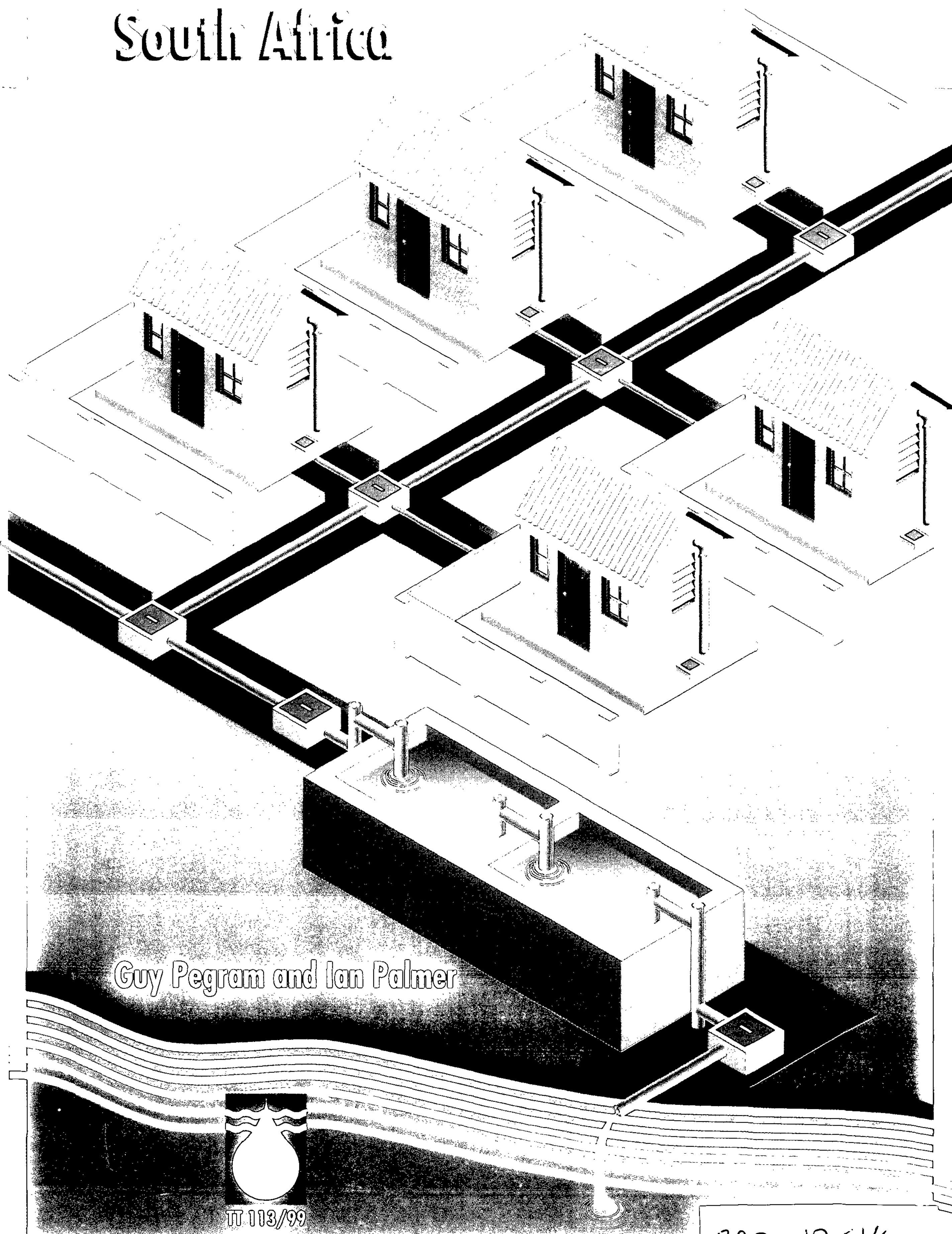
The Applicability of Shallow Sewer Systems in South Africa



Guy Pegram and Ian Palmer

TT 113/99

332-17614

THE APPLICABILITY OF SHALLOW SEWER SYSTEMS IN SOUTH AFRICA

REPORT TO THE
WATER RESEARCH COMMISSION

by

Guy Pegram and Ian Palmer

PALMER DEVELOPMENT GROUP

WRC Report No : TT 113/99
July 1999

LIBRARY IRC
PO Box 93190, 2509 AD THE HAG
Tel.: +31 70 30 689 80
Fax: +31 70 35 899 64
BARCODE: 17614

Obtainable from:

Water Research Commission
PO Box 824
Pretoria
0001

The publication of this report emanates from a project entitled: *The applicability of shallow sewer systems/simplified sewerage systems for dense urban communities in South Africa: An economic and technical appraisal* (WRC Project No. 983)

DISCLAIMER

This report has been reviewed by the Water Research Commission (WRC) and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the WRC, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

ISBN 1 86845 511 4
Printed in the Republic of South Africa

Acknowledgements

The financing of this project by the Water Research Commission (WRC) is gratefully acknowledged. The project was proposed and managed by Mr J Bhagwan of the WRC, and he is thanked for his vision and insights.

The authors also wish to record their sincere thanks to Mr Lukman Salifu and Mr Kofi Frimpong for their assistance with the site visit to Ghana and all the other researchers and practitioners throughout the world who have captured their knowledge of shallow sewers in various books and publications.

Executive Summary

Introduction

The provision of adequate sanitation has a major impact on health and quality of life and is thus a priority for South Africa. However, the level at which sanitation services are provided continues to be one of the most contentious issues for urban service provision, with politicians and civic organisations pushing for full waterborne sewerage, whereas local government treasurers see the high costs of these systems being unaffordable.

There are a number of intermediate sanitation technologies between on-plot disposal and conventional waterborne sewerage that may be considered for urban communities. This report evaluates the applicability of one such option for South African conditions, namely shallow sewerage. Although the appraisal addresses the technological components of these systems, the main focus is on the management arrangements required for successful implementation and operation of these systems. This is because internationally, the experience is that the institutional, financial and community participation components of these systems have the greatest impact on their sustainable operation.

Shallow Sewer Systems

Shallow sewer systems were developed by South American engineers in the early 1980s, in an attempt to provide an affordable sanitation alternative for dense, possibly unplanned, urban settlements. This is achieved by the following adaptations of conventional sewerage, which reduce the capital and operating costs of the systems.

Firstly, shallow sewerage, like simplified sewerage, is based on a relaxation of the typical technical specifications of conventional sewerage to reduce construction costs. This includes the use of smaller diameter pipes, flatter sewer gradients and replacing manholes with simple access points.

Secondly, block sewers are located within the residents' plots or under sidewalks, in order to reduce the length of piping and enable sewers to be laid at shallower depths because of the reduced loading. These block sewers connect to conventional trunk street sewers.

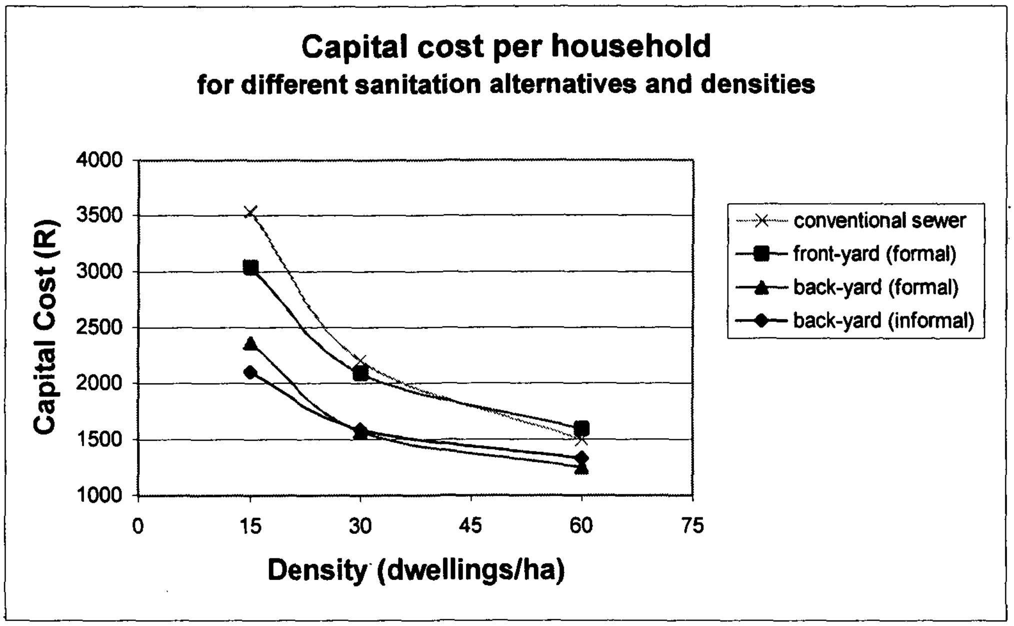
Thirdly, responsibility for maintenance of the block sewers may be delegated to the residents, thereby reducing the operating costs incurred by the service provider.

Satisfactory functioning of shallow sewer systems has been achieved under a wide range of conditions in Brazil, Ghana, Pakistan and Greece. It is particularly appropriate for upgrading of informal peri-urban settlements and for areas with intermediate levels of water consumption (30 to 50 ℓ/capita.d), but has also been applied in greenfield developments with higher levels of water supply. Nevertheless, successful implementation of shallow sewerage requires high rates of connection and extensive community mobilisation and support.

Costs of Shallow Sewer Systems

Shallow sewer systems were designed and costs were estimated for typical South African formal housing and informal peri-urban settlements, at different densities and for varying slope and geotechnical conditions. The figure below presents the capital cost comparison for internal infrastructure between back-yard shallow sewers, front-yard shallow sewers and a conventional sewer system at different densities, estimated using typical 1998 South African construction costs.

In the formal settlement, back-yard shallow sewerage ranges from 65% to 85% of the capital cost of conventional sewerage. The cost savings are greater for settlements with adverse geotechnical conditions, such as rock that needs to be excavated. Where residents contribute labour for the construction of the sewer systems, the capital costs may be reduced to between 50% and 70% of the cost of conventional sewerage. On the other hand, the total capital cost of internal and connector infrastructure for shallow sewerage is about twice that of VIPs.



The following table presents the average capital and operating costs of different sanitation alternatives, assuming that all maintenance is performed by the service provider. This indicates that the life cycle cost of shallow sewerage is about two and a half times that of VIPs, but only two thirds of conventional sewerage. However, if the residents are responsible for operation and maintenance of the block sewers, and contribute labour for construction, the annualised cost drops to almost a half of conventional sewerage (i.e. R26 per household per month). These cost estimates are consistent with the international experience and support the assertion that shallow sewers provide an intermediate sanitation alternative between VIPs and full waterborne sewerage.

Typical capital and operating costs for different sanitation alternatives (Rands).

	Capital (R)		Operating (R/month)			Total Annualised (R/month)
	Internal	*B & C*[1]	*Internal*	*B & C*	*Admin*	
VIP	1250	-	2.00	1.00	-	13
Shallow sewer systems						
- back-yard	1500	1000	7.00	3.00	4.00	31
- front-yard	2000	1000	8.50	3.00	4.00	36
Conventional sewerage	2100	1500	8.00	5.00	8.00	45

[1] B & C refers to bulk and connector infrastructure (outside the settlement area).

Financial analysis of the implementation of shallow sewerage with capital grant financing and delegated management of block sewers in a typical large metropolitan local authority indicated that the required sanitation tariff per household would be about R18 per month. This could be collected as part of the water tariff, or through rent or rates. This cost would increase to about R21 per month where the local authority took responsibility for all operation and maintenance.

The Applicability of Shallow Sewer Systems in South Africa

Based on the financial analysis and an evaluation of institutional and funding environment, the study indicated that shallow sewerage provides a viable intermediate sanitation alternative between on-plot VIPs and full waterborne sewerage. An evaluation of the different types of South African settlements in which shallow may be applied indicated the shallow sewers are most likely to be appropriate for:

- Upgrading of low-income informal settlements, where there is access to capital grant financing and community willingness to take responsibility for construction and operation of the block sewers.

- Upgrading of low to middle income formal or informal settlements with on-plot sanitation, where the community is committed to shallow sewers, has raised funds for materials and will take responsibility for construction and operation of shallow sewers.
- Upgrading of middle income settlements with on-plot sanitation, where cost recovery for services is high and the community is willing to pay the local authority for the full capital and operating cost of the sewerage system; this represents a technical rather than a management solution.

Although shallow sewer systems seem to be most appropriate for upgrading the above settlements with rudimentary on-plot sanitation, they may be applied in the following greenfield situations:
- Greenfield developments for an identified low-income community, with access to capital grant financing and a willingness to take responsibility for construction and operation of the block sewers.
- Greenfield developments for a middle income community, where full cost recovery for all services is expected and the local authority takes responsibility for all sewer maintenance.

Detailed recommendations about the institutional and financial arrangements required for shallow sewer implementation are provided in Chapter 5 of this report, together with and indication of the technical and social consultation issues that should be addressed.

Pilot Projects

Shallow sewer systems should be piloted in a couple of settlements to assist their further evaluation in South Africa. This may require technical standards to be relaxed and the setting up of designated shallow sewer teams in these local authorities. Social marketing and consultation are critical for the success of these initiatives.

It is proposed that these pilot projects be conducted in the larger local authorities, with Durban, Cape Town and Vereeniging being possible candidates due to their stated interest in this technology. The settlements that are selected for piloting should have the following characteristics:
- have a density of between 30 and 50 dwelling units/ha (du/ha), either formal or informal;
- have on-site water supply, preferably a yard tap, yard tank or house connection;
- have an existing inadequate on-plot sanitation alternative;
- be relatively stable, with recognised tenure;
- have community commitment to upgrading; and
- have an existing legitimate community organisation representing water and sanitation interests.

These pilot initiatives should be driven by the local authority, with technical support from the National Sanitation Coordinating Office (NaSCO). The WRC may provide further support for evaluating the pilot implementation, as well as promoting the technology to local authority politicians and officials, particularly in terms of the technical, financial and management advantages of these systems.

THE APPLICABILITY OF SHALLOW SEWER SYSTEMS TO DENSE SETTLEMENTS IN SOUTH AFRICA

Table of Contents

List of Figures

List of Tables

1 INTRODUCTION

1.1 The Challenge of Urban Sanitation

Providing adequate sanitation facilities for the urban poor remains one of the major challenges in all developing countries. In South Africa, about 11 million people in urban and peri-urban areas have inadequate access to sanitation, which provides limited protection for public health, the environment and water supplies. Typically, environmental degradation has the greatest impact on the health and resources of the poorest and most marginalised sections of society.

Providing services to these urban dwellers is complicated by the characteristics of the settlements in which they live:

- Settlements are located on the most marginal urban land, which is usually steep, rocky, prone to flooding and/or located away from sewered areas and treatment facilities.
- Population densities are high and open space is limited, often with irregular dwelling layout and unstable informal dwelling structures.
- Other service levels are low, particularly water supply and solid waste management, both of which have a negative impact on the effectiveness of sanitation solutions.
- Incomes are low, with widespread poverty and unemployment, resulting in limited affordability for improved services.
- Residents often have inadequate or illegal land tenure, which reduces the social stability of these settlements and often limits their recognition by government agencies.
- The marginal status of people in these settlements limits their political influence and ability to compete for resources and services.
- Residents of these settlements are often socially and culturally diverse, having migrated from various urban and rural areas, which can reduce the sense of community.

Many of these characteristics limit the applicability of on-site sanitation alternatives, either due to the risk to environmental health or because economies of scale make off-site solutions more cost-effective. Conversely, the capital costs and operation and maintenance requirements of conventional sewerage systems are unaffordable or unsustainable for transient settlements, even where these are appropriate to the physical conditions in the settlement.

1.2 The Strategic Sanitation Approach

A number of common elements have been drawn from successful sanitation interventions in a number of countries (Wright, 1997). Interestingly, these interventions were not radical departures from traditional technologies, but rather innovative approaches to applying them. They had the following features:

- Reflecting users' preferences and providing them with alternatives which they wanted and for which they were willing to pay.
- Unbundling discrete components of sanitation services, such as household connections, feeder and bulk infrastructure, and treating them differently for financing, construction and maintenance.
- Developing innovative institutional arrangements for these components, which reflect the abilities and comparative advantage of formal institutions versus informal residents' organisations, in terms of operation and maintenance.

The strategic sanitation approach attempts to capture these elements into a package of strategic measures to achieve the twin goals of sustainability and efficiency (Wright, 1997). Sustainable operation and expansion of sanitation coverage requires both operational and investment efficiency. Investment efficiency is dependent upon the three elements outlined above. Operational efficiency may be achieved through:

- Ensuring that the sanitation facilities are used as they were intended, through extensive user education and awareness creation programmes.
- Ensuring long-term and effective management of the facilities, through appropriate allocation of responsibilities and provision of resources for ongoing operation and maintenance.

1.3 Scope of this Report

This report provides an appraisal of the applicability of shallow sewer systems in South Africa. The project was funded by the WRC, as a contribution towards achieving strategic sanitation in this country, in the belief that shallow sewers could provide a low-cost intermediate technology sanitation solution, which is particularly applicable in dense low to medium income urban and peri-urban settlements.

The focus of this report is on the technical applicability, as well as the financial and management possibilities for these systems in South Africa. However, international experience has shown that the management arrangements govern the success of these interventions, and therefore the report reviews the social and institutional requirements for shallow sewers and presents an appraisal of their suitability in South African conditions.

Chapter 2 presents the technical characteristics and management arrangements of shallow sewer systems, and reviews a number of case studies where they have been applied internationally.

Chapter 3 evaluates the applicability of shallow sewer systems for settlements and conditions prevalent in South Africa, focussing on appropriate management arrangements and approaches to financing.

Chapter 4 estimates the likely capital and operating costs of shallow sewer systems in South Africa under different conditions, and compares these with other sanitation alternatives and the international experience.

Chapter 5 presents recommendation for implementation of shallow sewers in South Africa, proposing some criteria for possible pilot projects and outlining a way forward.

2 SHALLOW SEWER SYSTEMS

2.1 The Concept of Simplified Sewerage

The primary aim of shallow sewer systems is to provide an affordable sanitation option to accept both sewage and sullage within the constraints imposed by dense, possibly unplanned, urban settlements. In order to achieve this aim, shallow sewer systems are typified by:

- less stringent technical specifications than conventional sewerage;
- laying sewer lines through individuals' plots or under sidewalks rather than in the street reserve; and
- devolution of responsibility for sewer construction and maintenance to informal groupings.

In the following section, the general characteristics of shallow sewer systems are described according to these three issues, together with their advantages and applicability. This is followed by a review of case studies of the international experience with shallow sewers in Brazil, Pakistan and Ghana, as well as an initiative that was attempted in South Africa. Finally, the applicability of shallow sewers is summarised, together with key factors that have contributed to their successful implementation.

The high cost of conventional sewerage led to a critique and re-evaluation of the traditional technical design and construction requirements for conventional urban sanitation solutions by South American engineers in the early 1980s. This revision addressed the local environmental conditions and recipient community affordability in developing countries, as well as advances in sewer maintenance technology (Netto, 1992). It contributed to the proposed relaxation of technical specifications on components of the conventional sewer system, which is often referred to as simplified sewerage.

The urban sanitation reform strategy was based on the following seven principles, which would contribute to broadening service coverage and addressing the needs of the urban poor (Watson, 1995):

- *Adaptation to local conditions*, particularly the lack of financial resources, poverty and high unemployment which indicated the adoption of simple labour intensive techniques, as well as the physical characteristics of the settlement in which the system was to be implemented.

- *Community participation* to increase people's knowledge and promote organised action, thereby improving communication, decision-making and ownership.

- *Gradualism*, with the aim of providing affordable service levels to as many people as possible, with the possibility for upgrading as more resources become available.

- *Dissemination* of investment funding broadly to all local authorities, rather than a select few.

- *Differentiated services* enabled through provision of a basic level which is appropriate to the majority of residents, with those desiring higher service levels having to pay the additional costs.

- *Service integration* between related urban services to improve efficiency and lobby support for service improvements from a number of agencies.

- *Municipalisation* of services, based on urban local authorities being the most appropriate institutions for service provision in the interests of residents and community mobilisation.

These principles have been generally adopted in South Africa's National Sanitation Policy (NSTT, 1996), which provides the basis for evaluating the applicability of alternative approaches to sanitation. However, their implementation has not been particularly effective in peri-urban settlements throughout South Africa (NaSCO, 1998a).

2.2 Technical Characteristics of Shallow Sewer Systems

2.2.1 Technical Specifications

The shallow sewer system approach borrowed from and adapted the principles of simplified sewerage. UNCHS-HABITAT (1986) provides a detailed description of the design components of shallow sewer systems, a summary of which is presented below in section 2.2.3. The following inter-related technical characteristics are key to the reduction in costs and effective functioning of shallow sewer systems:

- *Location of sewers through plots or under sidewalks*, to reduce design loads and shorten the total pipe length required for connecting household water generating points to the sewer system.
- *High rates of connection*, based on widespread consultation and community engagement, together with the lower cost and ease of linking into the system; the household connections and feeder sewers are laid concurrently, which ensure that maximum benefit from the sanitation is enjoyed immediately upon installation.
- *Smaller diameter pipes* (100 mm), with frequent flushing associated with high rates of connection and generally higher population densities, increase the back pressure and improve the solids flushing capacity even at low volumes of water use.
- *Flat gradients* enabled by improved flushing action through small diameter pipes and site specific design for local conditions.
- *Shallow depths* enabled by locating sewers away from heavy street loads and using flat gradients.
- *Easy maintenance* access through shallow appropriately designed inspection chambers.

These relatively simple features reduce the capital and maintenance costs and improve the operation of the system for the following reasons (UNCHS-HABITAT, 1986):

- *Reduced water requirement* to prevent blocking, due to frequent flushing and small diameter pipes; successful operation has been observed in areas with average household water use of about 25 ℓ/capita.d, which in turn reduces water supply costs associated with the system.
- *Reduced pipe lengths* required to connect dwellings to sewers, and fewer feeder sewers required per street block; this is enabled by the location of feeder sewers through plots or under streets, close to the water generation points in dwellings, and efficient site-specific layout design.
- *Reduced excavation* for shallow trenches in which most of the pipe system is laid, minimises the exponential excavation costs and avoids destabilisation of informal poorly founded dwellings.
- *Reduced materials* associated with smaller pipe diameters and replacing deep manholes with shallow inspection chambers; sewer clearing may be performed by local people without expensive machinery, that has limited access in informal settlements.
- *Simple construction techniques* associated with the simplified specifications, enabling the use of less costly local contractors; nevertheless, the quality of the construction and supervision must be high, in order to avoid localised failure associated with the flatter gradients and smaller pipes.
- *Reduced operational requirements* associated with moving solids through small diameter pipes, gravity-fed systems and reduced pumping requirements; this reduces recurrent administrative and operational costs, particularly when linked to low maintenance localised treatment options.
- *Reduced maintenance requirements* associated with higher flushing capacity, shorter pipe lengths and easy maintenance access; this enables greater community participation in system maintenance, which may be more responsive to system failures and reduces recurrent institutional costs.
- *Localised treatment*, such as communal septic tanks draining to small bore sewers or local waste stabilisation ponds in each area, which is enabled by the shallow exit depths of the feeder sewers from each block; this should also reduce the connector sewer, pumping and treatment requirements.

The condominial system evolved in Brazil with innovative management arrangements, whereby responsibility for construction and operation of parts of the system were delegated to the residents. This is particularly appropriate were the system is laid through people's yards and further reduces the capital and operating costs of the system.

These features in turn make shallow sewer systems applicable to conditions in low to medium income peri-urban settlements. In particular, they address the problems of:

- *High population densities* which reduce the applicability of on-site sanitation systems (>40 du/ha).
- *Informal dwelling structures* which may be disturbed by deeper excavations.
- *Irregular settlement layout* and limited space to which conventional sewerage is not suited.
- *Difficult geo-technical conditions* that limit the applicability of on-site sanitation options and make deeper excavation more expensive.
- *Low water supply levels* (with lower consumption), such as communal standpipes and yard tanks.

2.2.2 System Layout

The sewer system layout is a fundamental element of the shallow sewer system approach (UNCHS-HABITAT, 1986). The shallow sewer system within a residential area (i.e. the internal infrastructure) may be viewed as having three main components, namely house connections, block feeder sewers (including the inspection chambers) and trunk sewers, as indicated in Figure 2.1. This does not include the bulk and connector infrastructure into which the internal sewerage drains, which includes the sewer outfalls, pumping stations and treatment facilities. The technical specifications of these components differ, but more importantly the responsibilities and approaches to planning, implementation and operation vary, as outlined in sections 2.3 and 3.3.

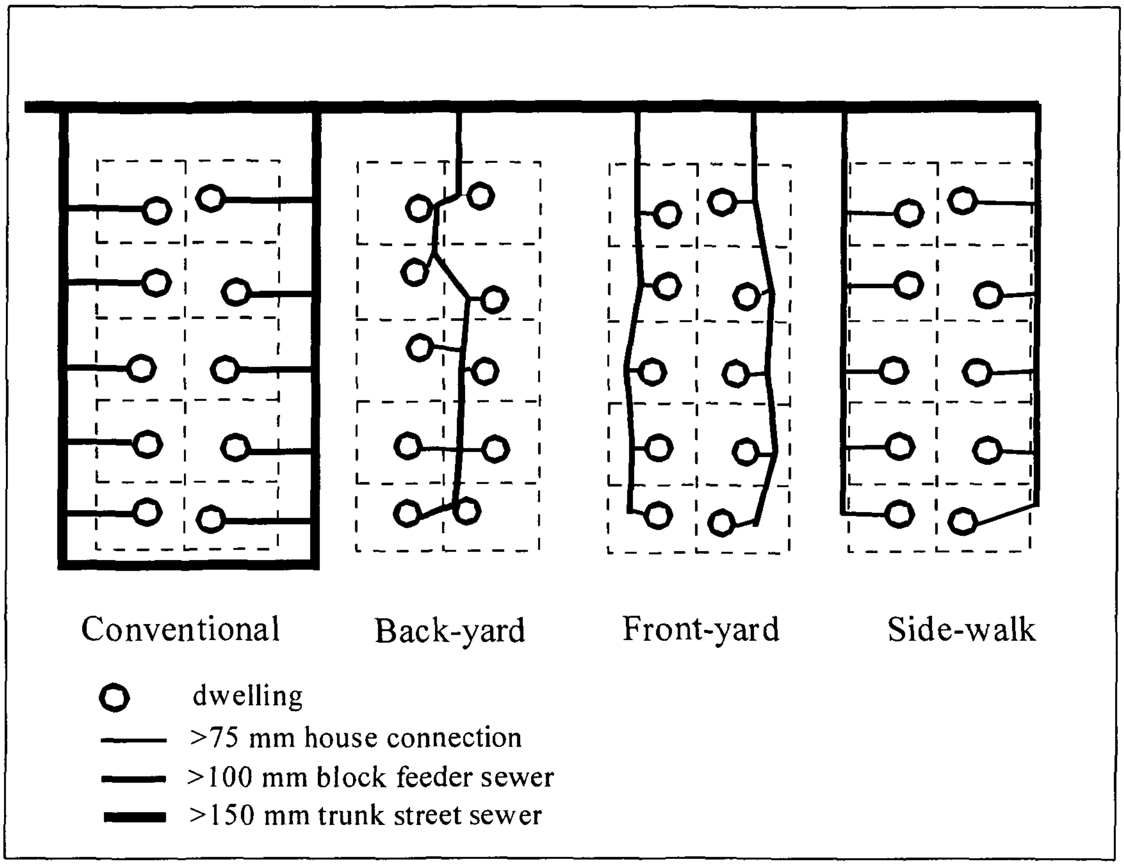


Figure 2.1. Layout of shallow and conventional sewer systems (Watson, 1995).

House connections

The house connections include all the in-house plumbing fixtures and the pipework connecting these to the inspection chamber on the block feeder sewer. Plumbing fixtures usually consist of a low-volume pour-flush or cistern-flushing toilet and a wash basin, although other fixtures such as kitchen or bathroom sinks, floor drains and showers may be installed. The toilet is connected to the inspection chamber by a 100 mm (or 75 mm) diameter connector pipe (with a vertical ventilation column) laid at a minimum gradient of 1:50. Sullage is connected via a 50 mm pipe laid at 1:200, possibly through a grit/grease trap for households with low water consumption. Installation and maintenance of the house connections are the sole responsibility of the dwelling inhabitants.

This part of the system is similar to house connections for conventional sewerage, except that a 1.5 ℓ flush volume may be used for shallow sewerage, while a 3 ℓ flush volume is the minimum recommended for conventional systems. This means that shallow sewerage may be used in areas with communal standpipes or shared yard taps.

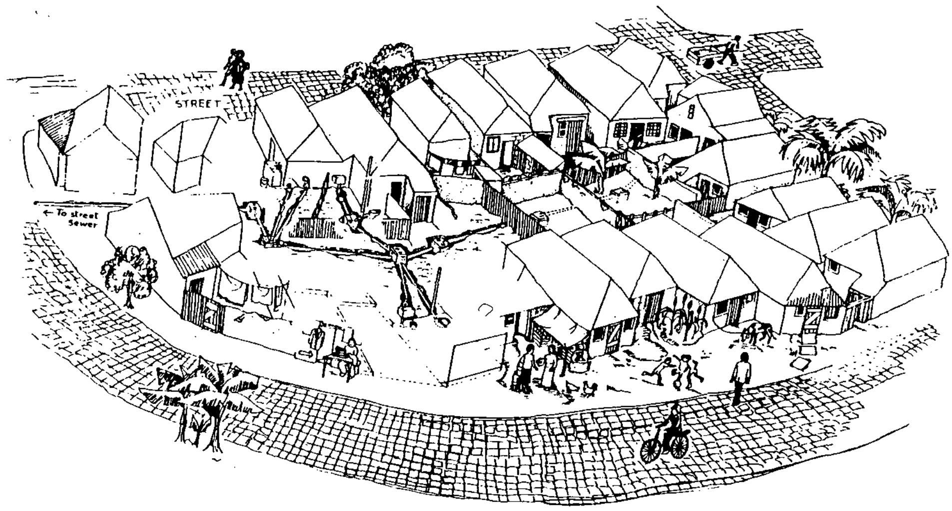


Figure 2.2. Illustration of a typical shallow sewer system (UNCHS-HABITAT, 1986).

Block feeder sewer system

Small-diameter (at least 100 mm) block feeder sewers are trenched through people's plots or under the sidewalk, deep enough to collect wastewater discharge from adjacent dwellings. The block sewers are laid in a straight line between inspection chambers, at a constant gradient greater than 1:167, with at least 400 mm cover to avoid accidental damage. The depth of the feeder sewers must also be adequate to ensure the 1:50 gradient of the house connection. Figure 2.2 illustrates the layout of house connections, inspection chambers and feeder sewers in a residential block.

Inspection chambers are located in open areas at regular intervals along the feeder sewer line, in order to provide for house connections and to facilitate access for sewer maintenance. They are sized according to the depth of the sewer, with a tight fitting cover. One inspection chamber is usually allocated per household, as near to the wastewater generating point as possible, with the alignment of the feeder sewer being contoured around dwelling structures and under walls. Responsibility for installing and maintaining the block sewer system falls jointly on the block residents with assistance from water service institutions, as outlined in section 2.3.

The three basic shallow sewer alternatives are the back-yard, front-yard and sidewalk systems, as illustrated in Figure 2.1. These systems have the following features:

- *Back-yard systems* have the advantage that only one feeder sewer is required per block and this is usually closer to the water generation points at the rear of dwellings, thereby reducing the capital costs. However, the lower visibility of this system has resulted in poor monitoring by the community, leading to inadequate maintenance by the household.

- *Front-yard systems* require two sewer lines per block and usually require greater pipe length for the household connections, because they are further away from the water generating points. This makes them more expensive than back-yard systems, but their higher community visibility generally contributes to improved community and individual maintenance.
- Sidewalk systems also require two sewers per block, must be laid slightly deeper to prevent damage and are located further away from the dwellings, which makes them the most expensive alternative. The disadvantage is that residents do not usually accept maintenance responsibility for sewers located off their plots.

Arrangements have been made for individual households to connect directly to the bulk sewers under the sidewalk, in order to provide them with a conventional sewer system. However, they have to bear the full costs of the household and sewer connection.

Block feeder sewers are different from conventional street sewers in three main ways, namely the pipe diameters are smaller (minimum 100 mm versus 150 mm), the gradients are flatter (1:167 slope versus 1:67 conventional sewerage slope for less than 150 connected households), and inspection chambers are used rather than street manholes. The reduction of the number of manholes considerably reduces the costs of construction of shallow sewers, as manholes are only needed for street sewers.

Trunk street sewer system

The trunk sewer system is located in the street and may be designed in accordance with conventional, simplified or small-bore sewer principles, depending upon the local treatment facilities. Many pilot shallow sewer systems are implemented on a single street block as "stand-alone" systems with communal septic tanks and/or waste stabilisation ponds providing treatment. Trunk sewers should be laid under street sidewalks where possible, but deep enough to receive the block feeder sewer discharge or to ensure about 1000 mm cover under streets. Typically, 100 mm diameter pipes may be used for up to 70 house connections, increasing to 150 mm (or greater) as the number of connections increases. They should be laid at a gradient that ensures continuation of the flow, i.e. a slope of 1:167 flattening to 1:200 after 150 household connections (see below).

Trunk sewers for shallow and conventional sewerage are similar, except that shallow sewers are initially laid at flatter gradients and the outfall depth of a feeder sewer from a street block is typically much shallower than the equivalent conventional street sewer. Furthermore, adjacent blocks may be connected by a shallow sidewalk sewer with inspection chambers, rather than a full trunk sewer with manholes.

2.2.3 Overview of Shallow Sewer Design Guidelines

The following discussion provides an overview of the important hydraulic design criteria for shallow sewers. It is meant to highlight the design philosophy for technical readers, rather than be a design manual. Detailed design criteria and specifications are presented in UNCHS-HABITAT (1986).

Conventional sewers are usually designed to ensure that peak daily flows carry away any solids that are deposited during periods of lower flows. However, recent research has indicated that requiring these self-cleansing flows results in conservative designs. In reality, smaller diameter sewers are flushed by the pressure force caused by water backing up behind the deposited solids. Solids are thus moved along the pipe by the flushing action of sequential waves of wastewater. The design of shallow sewers is based on these findings, rather than the traditional self-cleansing velocity design criteria.

Minimum and maximum flow velocities

Relaxing the principle of self-cleansing velocities in shallow sewers implies that the minimum flow velocity may be reduced from 0.7 m/s (Dept. of Housing, 1994) to 0.5 m/s (UNCHS-HABITAT, 1986). Although a maximum flow velocity of 4 m/s is sometimes specified, this is not necessary, because erosion of PVC piping above this velocity has been found to be negligible.

Minimum and maximum depth of flow

Following accepted practice, a minimum depth of flow of 0.2 times the pipe diameter (to ensure solids transport) and a maximum of 0.8 times the pipe diameter (to provide surplus capacity) are recommended.

Minimum sewer diameter

As outlined above, shallow sewers use 100 mm piping where possible, only increasing this where required by an estimate of the peak sewage flow. A general guideline is for 74 households to be served by 100 mm diameter piping (UNCHS-HABITAT, 1986), although Mara (1996a) proposes that this may be increased to 234 households with low water consumption.

Minimum sewer gradient

Minimum pipeline gradients are related to the pipe diameter and minimum velocity. The Red Book (Dept. of Housing, 1994) specifies a minimum 1:120 gradient for 100 mm piping and 1:200 gradient for 150 mm piping. With a relaxation of the minimum velocity (0.5 m/s), and using the limiting conditions outlined above (minimum depth of flow of 0.2 time the pipe diameter in the upper reaches of the sewer network), Manning's equation simplifies to (with a roughness coefficient n = 0.13 for slimed PVC piping):

$$I = 0.01\,Q^{-2/3}$$ (UNCHS-HABITAT, 1986: pg 22)

where I pipe gradient (m/m)
Q flow rate (l/s)

This implies that the minimum permissible gradient is independent of the pipe diameter for a given flow. Based on these findings and a minimum peak flow of 2.2 l/s, a minimum gradient of 1:167 has been recommended for block shallow sewers in areas of low water consumption serving 60 households (UNCHS-HABITAT, 1986; Mara, 1996b). This may be reduced to 1:200 for 150 mm diameter pipe connecting more than 200 houses, following accepted South African practice.

More recently, experience in Brazil has led to the use of minimum tractive tension in the design of shallow sewers to reflect the pressure build-up from water backing up behind solids (Mara, 1996b). This approach results in even flatter sewer gradients (i.e. 1:255), which have resulted in satisfactory operation in Brazil, based on the following equation (Mara, 1996b: p 123):

$$I = 0.00564\,Q^{-6/13}$$

In areas with very steep slopes, it may be necessary to apply a maximum sewer gradient based on conventional experience, with a drop manhole placed to step the sewer down where necessary.

Peak sewage flow estimation

Calculation of the design peak sewage flow rate at various stages in the pipe network for less than 1500 people, should be based on the following equation from the Red Book (Chapter 9: p 15), assuming infiltration of 15% and a peak factor of 2.5:

$$C = \frac{A}{30\,000}\ l\text{/s.du}$$

A is the average daily sewage flow rate, which is equivalent to about 80% of the household water consumption. Shallow sewers are generally implemented in areas with lower income and water supply levels, i.e. between 150 and 350 l/du.d. This implies a peak flow rate between 0.004 and 0.01 l/s.du.

The pipe flow capacity at any stage in the sewer network should be adequate to carry the peak flow rate, taking account of the permissible limits for the depth of flow. This may be evaluated using Manning's equation or any equivalent simplification.

2.3 Management Arrangements

2.3.1 Management Obstacles for Shallow Sewer Systems

One of the key features of shallow sewer systems is the devolution of responsibility for maintenance of the block feeder sewers to the residents (i.e. sewerage customers), while water service providers retain responsibility for the trunk sewers and treatment facilities. In theory, devolution reduces institutional costs and makes maintenance more responsive to the needs of local residents.

Unfortunately, the reality has not worked as well as it could, often due to the specific social character of the communities in which these systems are implemented (section 1.1). These problems are often compounded by the management environment in the water services institutions, which are not oriented towards supporting intermediate service levels. The following issues highlight potential social and institutional difficulties in planning, implementing and maintaining shallow sewer systems in peri-urban settlements:

- These settlements are often transitional, with uncertain land tenure, which reduces the interest of local residents in contributing to infrastructure development.

- Marginal (and possibly illegal) status contributes to a poor relationship and lack of trust between residents and government institutions.

- Residents usually have limited knowledge of the use of sewerage systems and lack the expertise to perform more complex construction and maintenance tasks.

- Despite the presence of community associations, residents may not be prepared to collaborate in maintaining sewers.

- Without collaboration, the maintenance task falls on those residents who suffer most from system failure, usually located in low-lying areas at the bottom of the system.

- Unemployment and poverty is usually endemic in these communities, which reduces people's willingness-to-pay for improved services and maintenance, unless they are directly impacted or are aware of the implications of non-payment.

- Technical personnel in water services institutions are generally not aware of the benefits of intermediate sanitation options, and are uncomfortable with the required consultation processes.

- Operation and maintenance is usually not a high political or institutional priority, because it has less profile than capital projects and is only an issue when it is not working.

Experience has shown that successful devolution of responsibility requires greater interaction between the water services provider and the residents than for conventional sewerage systems. This should occur during the planning, construction and operational phases of the project implementation; devolution without support leads to breakdown of the system.

2.3.2 Customised Service Approach

The success of any sanitation service intervention requires more than pipes and toilets. It depends upon community mobilisation, good health and hygiene practice, user education and creation of environmental awareness. This is even more relevant for shallow sewer systems, because the approach requires community acceptability and ownership in settlements with many of the difficulties highlighted in the previous section. Without these, the requirements for technical functioning of these systems are unlikely to be met, namely high connection rates, local responsibility and resident contributions to system construction and operation. These requirements are fundamental if the two key strategic sanitation goals of sustainability and efficiency are to be met.

The approach underlying shallow sewer systems is based upon providing a range of technical options and involving settlement residents in the selection of service, financing and maintenance arrangements. This customer service approach has the following key features (Watson, 1995):

- *Community mobilisation* before construction to enable the process of project introduction, as well as conflict and negotiation around service levels, financing and responsibilities.
- *Multi-disciplinary implementation teams* which supply both the technical skills for service provision and the social process requirements for community involvement and capacity building.
- *Complementary services* with house connections being the responsibility of the household, supported by technical assistance from the project, in order to increase connection rates.
- *Customised household layout* for the location of the block feeder sewers to suit household water generation points and reflect possible future household development.
- *Pilot projects* in each new settlement area to help the community learn and experience the system and possibly adapt it for local conditions.
- *Gradual acceleration* of project pace to enable adequate community mobilisation initially and then provide incentives to speed up the implementation of the system.
- *Accountability mechanisms* for construction quality and project design using local contractors, as these are the most common causes of poor technical performance.

2.3.3 Social Marketing

Shallow sewer systems depend upon community mobilisation, acceptance and ownership. This requires a significant investment of time and effort in public consultation and education, before, during and after the implementation of the project. Technical options, financial implications and maintenance requirements should be presented, together with discussions of the advantages and disadvantages of various alternatives. This should lead to negotiation and agreement about the maintenance and financial arrangements before the project is implemented. Social marketing initiatives should include the following:

- The planning of a project must start with an initiation meeting for each block, with a requirement of at least 50% attendance by the block residents.

- Follow-up meetings are required to continue the momentum and ensure that all residents are happy with the process and selected approach.

- Intensive health and hygiene education and environmental awareness programmes should be initiated during the planning phase to provide added impetus to the community mobilisation and demand creation process.

- The use of local contractors encourages support by the community and transfers maintenance skills into the community, but requires training, capacity building and effective quality control during construction.

- User education and capacity building programmes also need to be conducted during implementation and on a continuing basis, in order to reduce maintenance requirements, particularly in more transient communities.

2.3.4 Roles and Responsibilities

Appropriate institutional roles and responsibilities and the energy and resources provided during the project cycle are critical to the success of shallow sewer systems. Interaction and communication between the community and water services institutions must begin at the planning phase, be carried through design and construction, and maintained during operation and maintenance. Third parties, such as community associations and NGOs also have a role to play in mobilisation and mediation throughout the process. The institutional requirements of these groups are outlined in the following discussion.

Water services institutions

The South African Water Services Act (1997) distinguishes between water services authorities (usually the local authority) who are politically responsible for ensuring the provision of water supply and sanitation services to communities, and water services providers who are responsible for the actual provision of these services.

Water services authorities and water services providers usually provide the initial energy for shallow sewer systems, through social mobilisation and community consultation. In the most effective examples, the water services provider has a dedicated multi-disciplinary team that is only responsible for shallow sewer promotion, implementation and maintenance. The same group of personnel should be responsible for all phases of the project, so that the skills, sensitivities and experience gained during planning and construction are available for system operation and maintenance, thereby providing feed-back for future expansion. This team may be led by a couple of technical and social managers, but consists largely of community liaison officers and technicians.

The minimum responsibilities of water services providers are:
- operation and maintenance of the bulk and collector sewer system, including treatment facilities;
- correcting design and construction problems in the internal (trunk and feeder) sewer systems; and
- conducting education on system usage and maintenance, as well as health and hygiene practices.

The low priority of sewer operation and maintenance in local authority budgets and structures, has often led to these responsibilities being inadequately performed. Where there is political or bureaucratic resistance to intermediate sanitation systems, this poor performance has often been intentional, possibly motivated by a desire to sabotage the success of shallow sewer systems. Unfortunately, the nature of shallow sewer systems is often blamed for these problems, rather than the root cause of problems in the institutional arrangements. The reality is that shallow sewers generally function as well as conventional systems in lower income areas.

The success of shallow sewers is dependent upon a team of committed and appropriately skilled personnel in the water services providers, who interact on a regular basis with their customers (i.e. residents), but also have the political support to drive the process of gradual expansion of shallow sewer systems.

Settlement Residents

Shallow sewer systems depend upon active involvement of residents in planning, construction and maintenance, which can only be achieved when there is adequate knowledge and ownership of the project by the community. Creating this situation is the responsibility of the water services providers, through intensive and ongoing interaction with settlement residents.

The original conception of shallow sewer (condominial) systems was that the community would individually or collectively maintain the block feeder sewers. Unfortunately, experience has shown that residents do not tend to collaborate very effectively to maintain sewer systems, unless there is a strong community organisation coordinating the process. This problem is compounded by the limited skills in these communities, particularly to resolve chronic problems that are related to design or construction flaws.

Often the residents who are directly affected by a problem end up individually solving it, particularly in poorer communities that cannot afford third-party maintenance. The residents in other parts of the system are oblivious to these problems, because their part of the system is operating adequately. Individual action often only addresses the symptom, rather than the underlying cause, which may be related to inappropriate usage or construction. The causes may only be addressed where there is active involvement of community organisations.

In some cases, one person on the block has been designated to take responsibility for maintenance and to keep any equipment that may be required. This approach has not always worked particularly well, because people tend to solve their own problems where possible and in many cases other residents do not know who that person is six months after completion of the system.

In order to address this problem, many medium-income communities have paid for a third party to take responsibility for this maintenance, and this has been relatively successful where it is affordable. This indicates that a designated paid resident may be a more effective solution to the maintenance problem.

Third parties

Third parties, such as NGOs and community associations (e.g.civics and water and sanitation specific CBOs) have three possible roles with respect to shallow sewer systems. They may be:

- *Community advocates* that articulate problems and grievances to the water services authorities (or providers) and pressure government for action. This is the most common role of community associations, which ensures continued pressure for system expansion and service accountability.

- *Organisers of collective action* for system maintenance, where it is not being adequately performed by individuals or the water service institution. This is often the role of NGOs, particularly in association with community associations.

- *Service contractors* where communities demand immediate resolution of sewer maintenance problems, which are not being addressed by the local authority, particularly when they do not wish to jeopardise their prominent position in the community. This is the institutional model that has been adopted in many rural areas throughout South Africa.

As community associations and NGOs become more involved in "doing things", rather than "making demands", they are required to address financing of operation. This introduces additional complexity and difficulty to their role, particularly when the project must be financed through internal cost-recovery, rather than from external funding sources.

However, the desire by communities to arrange and in some cases pay for third-party sewer maintenance, indicates that there is a "market" for this service, particularly where residents believe that the water service provider is not likely to take this responsibility and this service is affordable.

2.3.5 Financing and Cost Recovery

Financial sustainability is one of the most critical issues for any sanitation intervention, but is one that has not been adequately resolved in many developing countries. Various approaches have been attempted for financing and cost recovery associated with shallow sewer systems. Capital costs are dealt with separately from operating costs in the following discussion.

Capital costs

Capital costs for sanitation interventions are often financed through grant or subsidy funding, justified by the associated social benefits, such as public health, human productivity, environmental protection and urban development. Even where intermediate levels of service (including shallow sewers) are installed, politicians are often reluctant to enforce capital payments by poorer communities, particularly where higher service levels to more affluent areas have been historically subsidised. On the other hand fiscal constraints on local authorities have required up-front or deferred capital payments from recipient communities, sometimes as "in kind" contributions.

In fact, people who have paid an up-front connection fee are more likely to take ownership of the installed system. Willingness to pay this fee indicates affordability for operational costs and a commitment to the project. Up-front payments may be financed through low interest commercial loans to the community. In practice, those projects for which capital contributions were required from a large portion of the block before construction had higher connection rates and improved operation, even though the implementation process was delayed.

Financing of capital costs may be addressed differently for the three system components, particularly where construction and maintenance responsibilities vary:

- House connections should be financed by individual beneficiary households, whether this is as part of an initial connection fee or directly to a recognised plumber. In the latter case the water service institutions may support households to access materials at lower costs.

- Block feeder sewer systems may either be fully subsidised or financed as part of the residents' connection fee, depending upon the availability of grant funding. This should also be linked to the agreed maintenance arrangements, because people are less likely to maintain infrastructure that has been financed and constructed by external agents.

- Trunk street, collector and bulk sewer systems have generally been funded through external grant financing or the water services provider's own funds, and are generally the responsibility of the water service provider.

Financing the "soft" social marketing component of shallow sewer systems, such as community consultation, health and hygiene awareness and user education, may be argued to have a broader social benefit and should therefore be financed by government or the water services institutions. This part of sanitation programmes is often government financed, with residents only being responsible for the infrastructure capital costs. The approach depends upon creating a demand for sanitation, for which people will be willing to pay.

Cost recovery for sewerage systems is typically very poor. Therefore, every attempt should be made to recover any capital costs from the community as up-front payments, rather than amortising these capital costs and recovering them as part of the operating expenditure over time (e.g.20 years). Otherwise, poor cost recovery may jeopardise the sustainability of service expansion or place too great a burden on cost recovery for system operation. Deferred capital recovery should only be considered in cases where existing levels of payment are high, or effective sanction is possible.

Operating costs

The sustainability of shallow sewer systems depends upon cost-effective operation and maintenance, financed through user charges. Unfortunately, there is little information internationally about the actual operation and maintenance costs of shallow sewer systems, under different institutional arrangements. Where shallow sewer tariffs have been charged, these have typically been arbitrarily set between 30% and 60% of the water tariff. This has been complicated by the separation of water supply and sanitation responsibilities in many developing countries, as well as the political imperatives to keep service costs low.

Devolution of responsibility for maintaining household connections and block feeder sewers to residents enables the reduction of operational tariffs. However, this devolution has been most effective where there is a strong residents association that has organised and collected money to fund sewer maintenance. Where this has not happened, the systems have often failed with people even reverting to on-site sanitation systems. Alternatively, political pressure has resulted in the local authority maintaining the system as part of their general sewer maintenance programme, without collecting any charges.

As with the capital costs, operation and maintenance of the trunk street sewers, collector sewers and bulk treatment facilities are often funded from municipal budgets or grant financing, particularly if the residents are maintaining their own block sewers. On the other hand, if sewer tariffs are being collected, charges for discharging into the collector sewers may be added to these, reflecting the operating costs of the bulk and collector systems.

An alternative approach to collecting operation and maintenance charges is as a fixed amount as part of the land tax or rent, as is done in many formal urban areas. However, this approach is not appropriate where people have no tenure, or rental payment is low. Furthermore, it does not link sewer usage charges to water supply, which disadvantages poorer households that use less water.

2.4 The International Experience

2.4.1 Introduction

During the past 20 years, shallow sewer systems have been implemented in a number of settlements and cities throughout the world, including middle class areas in the United States, Australia and Greece. However, the focus of this study is on lower income communities in developing countries. The following five case studies provide an overview of shallow sewer system implementation in Brazil, Pakistan, Ghana and South Africa. Two of them are located in Brazil (as this is the country in which shallow sewers were first developed), but these illustrations cover a range of social, economic and cultural conditions, with differing water-use characteristics. These contrasting conditions indicate the widespread applicability of this technology for urban settlements. Mara (1996a) and Watson (1995) provide other case studies of shallow sewer implementation.

2.4.2 Natal, Rio Grande do Norte (Brazil)

Shallow (condominial) sewers were first implemented in Natal, the capital city of Rio Grande do Norte, with a population of about 600 000 people (Watson, 1995). Since it was first implemented in the early 1980s, sewer coverage has doubled and no further conventional sewerage has been developed in the city, even in higher income areas. This application was unique, in that a low-cost technology requiring a participatory approach was driven by a small group of progressive engineers, within the state water company (CAERN), led by the system developer Jose Carlos de Melo, rather than the local authority.

The new approach was not widely accepted by the technical personnel in CAERN, and the operations staff ignored the system for the first five years. This led to severe breakdown of the system, due to blockages in the trunk sewers and the inability of local residents to address the more chronic problems associated with design and construction flaws. Finally, the operations staff started clearing both the trunk collector and block feeder networks, and this situation has been continued to date, even though the original intention was for residents to maintain the local block sewers.

However, severe breakdown of parts of the system was still not being addressed by the operations staff. Eventually, the construction division became involved and replaced parts of the system. At this time, members of the original development team were transferred into operations division, to create a dedicated maintenance crew, which also consisted of a social worker. They developed a customised rapid response maintenance approach, which included system monitoring and community education. This approach has proven to be less expensive than maintaining conventional sewer systems.

Rocas and Santos Reis are two informal settlements in Natal consisting of about 15 000 people at a density of about 350 people per hectare (UNCHS-HABITAT, 1986). The implementation of shallow sewers in these settlements provides some pertinent lessons. Even though these spontaneous settlements are both poor, with limited formal planning, the issuing of land tenure resulted in solid dwelling construction with good building materials. Most dwellings had an unmetered yard tap and paid a set water tariff for an average of 45 *ℓ* /capita.d.

In the early 1980s, it was decided to upgrade the existing on-site sanitation. Public meetings were held to present the advantages and disadvantages of different sanitation options. A shallow sewer pilot block consisting of 28 houses was developed, draining to a communal septic tank. Its successful operation over the year of planning for the sanitation intervention addressed the community concerns that it would have high maintenance requirements. This resulted in a high 97% connection rate on implementation.

A back-yard system was adopted, due to space constraints, with small local contractors connecting block sewers and large contractors constructing the trunk collector sewers. Local labour was used for construction where possible. The capital cost of the system was $325 per household, which was recovered through a 40% surcharge on the household water bill. A study of the system has shown that shallow sewers were less expensive than on-site sanitation options at densities greater than 160 people per hectare.

2.4.3 Petrolina, Pernambuco (Brazil)

Petrolina, a city of about 140 000 people in the Pernambuco province, was the second major shallow sewer system intervention, beginning in 1983 (Watson, 1994; 1995). As in Natal, shallow sewers are now the service norm, representing 70% of all sewers in the city; total sewer coverage is about 60%. Both the municipal government and state water company (COMPESA) have developed shallow sewers in Petrolina. However, the municipality has generally taken the lead in social mobilisation and construction of the systems, with some assistance from COMPESA for construction of bulk collector sewers.

Although there has been varying commitment to community mobilisation and limited support by many engineers in COMPESA during the past 15 years, a culture of shallow sewer systems has developed and been institutionalised. Residents now expect shallow sewer systems and it has become a significant political issue.

The cost of shallow (condominial) sewer systems has tended to be 60% to 80% lower than conventional sewerage, while providing a comparable level of service. Households are expected to pay a connection fee, which is highly subsidised, and then pay a percentage of water tariffs for recurrent costs. However, no attempt has been made to evaluate whether the tariffs cover the costs. Furthermore, COMPESA only agreed to transfer 75% of the sewer tariff to the municipality in 1994, which had further constrained the resources available to the city to maintain and extend their system.

During the early 1990s, the participatory aspects of shallow sewer implementation in Petrolina were reduced due to budgetary constraints. This led to engineers imposing system configuration on communities, which reduced the acceptability of the systems. Cost savings were not as good, system performance was reduced and customer satisfaction was low.

Implementation of the system has resulted in significant improvements in environmental health, with incidents of infant diarrhoea in areas with shallow sewers being half that of unserviced areas.

The first pilot project in Petrolina was implemented in the central city area of Vila Moco, largely due to the energy of an active community leader (Watson, 1994). The municipality selected this area, based on the residents' willingness to pay for pipes and provide labour for the block feeder sewers, while the city paid for the trunk collector sewers.

Active mobilisation took part on a block by block basis, with the assistance of Dr Melo, his consulting company and local vocational training school graduates. Residents were informed about the system functioning, layout and financial requirements. Initially, the community had difficulty in raising the upfront payment. However, once the first block had a system implemented, and the benefits were tangible, other blocks quickly raised the funds and the system expended rapidly. Once this pilot project was shown to be a success, the World Bank-funded Medium Sized City Project provided financing to the city to build condominial systems, which led to its widespread application.

Since this time, shallow (condominial) sewer systems have been implemented throughout Brazil, with varying success. Watson (1995) provides an overview of the experience in other cities, including Brazilia, Itapissuma, Recife, Joinville and Cuiaba.

2.4.4 Orangi Pilot Project, Karachi (Pakistan)

Orangi is the largest informal "squatter" settlement in Karachi, with an estimated 900 000 people (UNCHS-HABITAT, 1986; Wright, 1997) on 2 000 hectares. The settlement lacked rudimentary services, poverty was widespread and health problems were rife. Bucket latrines and vault toilets were the norm, with public standpipes supplying on average between 20 and 30 *l* /c/d. There were no sullage disposal facilities. Many parts of Orangi have a regular layout, with a narrow service lane in between. This provided the opportunity to construct shallow sewers which, if designed appropriately with high levels of connection, can function at these low levels of water usage.

Starting with a pilot project of 555 plots in Chisty Nagar, extensive community mobilisation took place to encourage the community to contribute funds to the development of shallow sewers draining to a communal septic tank. Once the funds were raised, the system was constructed and proved to operate adequately. This initial project failed to develop a strong community organisation capable of maintaining the system.

However, since this pilot project, an innovative community organiser, Akhtar Hameed Khan, has built up local organisations, which have been extending the approach throughout Orangi and lobbying the Karachi municipality to provide funds for bulk sewers. The community raises their own finances for installing household connections and block feeder sewers in their lanes (about $25 per household), participates in construction and elects a "lane manager" per 20 to 30 households for maintenance. Orangi Pilot Project engineers assist the local communities in planning, design and construction. This initiative has achieved a remarkable 90% shallow sewer coverage of Orangi since 1983, and illustrates that people's demands for intermediate levels of sanitation can incrementally be translated into reality with adequate empowerment, even at low levels of water consumption.

2.4.5 Asafo Simplified Sewerage Scheme, Kumasi (Ghana)

Kumasi is a city of about 770 000 people in southern Ghana, in which about 75% of the population lacked access to adequate sanitation before 1991 (Wright, 1997; KMA, 1991). The Kumasi sanitation project was initiated to tailor sanitation provision to household types and be demand driven. The World Bank funded project was based on a willingness-to-pay survey that indicated that most households were prepared to contribute to improved sanitation services, but that the potential revenues would not be large. In fact, the poorest households were already paying relatively large amounts to use public facilities.

Conventional sewerage was not affordable without large subsidies. A strategic sanitation approach was adopted, whereby a mix of Kumasi VIPs and isolated sewerage with communal septic tanks were provided in the less dense parts of the city and a simplified shallow sewer system was developed in the densely populated Asafo tenement area.

The Asafo district is in the Central Business District of Kumasi and consists of 2- to 3-story buildings that were largely built before independence (Salifu, 1998). (See Addendum B for a description of water services in Ghana, based on a site visit during 1998). It is predominantly residential, with some commercial activity, and is laid out on a block system with a narrow back service lane in between housing rows. Each tenement consist of 20 to 30 rooms, housing between 10 and 20 families (40 to 100 people), and are generally built on the edge of the 30 m by 30 m property with a central courtyard. The population density ranges from 300 to 600 people per hectare. Most tenements have a single metered water supply, which currently achieves about 85% payment levels, largely due to the threat of disconnection.

Ghana has had a negative experience with conventional sewerage and on-site septic tanks in dense areas such as Asafo, leading to breakdown in operation, backlogs in maintenance and surcharge into nearby drains. This led to the selection of a simplified shallow sewerage system with a gravitational trunk sewer feeding a low maintenance waste stabilisation pond system, as the least cost and most sustainable option for Asafo. Estimates indicated that the shallow sewerage capital cost was less than 55% of the capital cost for conventional or small bore sewerage systems, with maintenance costs of the same order.

The pilot project in part of Asafo began with an intensive community liaison process by the community development officer of the Waste Management Department. The trunk collector and block feeder sewers were planned, designed and constructed at the same time and completed by 1995. The sewer system configuration was constrained by the street block and tenement layout and the topography of the area, so there was little consultation about this component of the project. The intention was to get a system in place to accelerate the process and provide a pilot example of the functioning system.

Construction of the trunk and block sewer system was funded by the World Bank, at a capital cost of about $55 per capita. Residents only had to pay the full cost of the household connections, which currently ranges from $200 to $700 per tenement, or $5 to $15 per capita, depending upon the household plumbing fixtures that they chose. Only the local contractor is supposed to construct household connections, in order to maintain construction quality control over this key component of the system. Inadequate system maintenance by the community led to the local contractor being awarded a two-year contract to maintain the system, until higher connection rates have been achieved and a management system is in place.

By mid 1998, only about 50% of the residents have connected legally to the system, although there are indications that other unauthorised connections have been made. There have been on-going efforts to increase awareness of the project and motivate connection, but these have been *ad hoc*, rather than part of a systematic social marketing programme. As a result, residents have been hesitant to connect, even though they indicate support for the project.

This unwillingness to connect has also been influenced by the perceived increase in water usage and associated water bills. Unfortunately, the multi-family tenements are penalised, because they pay the same rising block tariffs as single family households. They therefore are paying for water at the highest marginal rate, even when their per capita consumption is only 50 *l* /c/d. There is currently discussion by the project team to sanction (fine) those tenements that have not connected by a given date.

Although the system has been operating for three years, it still remains transitional. In fact, it is more of a technical simplified sewer system, rather a shallow sewer system with innovative management arrangements. This is largely due to the low connection rates and incomplete changes in the water services sector in Ghana. Fortunately, sewer blockages are infrequent and thus there are few maintenance requirements, even though the stabilisation ponds are not operating perfectly. Once the system is fully operational, the following operation and maintenance management arrangements are intended (Salifu, 1998):

- The Kumasi Metropolitan Assembly Waste Management Department (KMA-WMD) will be responsible for operating and maintaining the trunk system and waste stabilisation ponds.
- The Asafo residents will be responsible for maintaining house connections through block committees.
- The area will be designated the Asafo Tenement Sewerage Connection Area under local government legislation, requiring all buildings to connect to the system.
- The KMA-WMD will levy sewerage charges as a percentage (about 25%) of water bills, through the Ghana Water and Sewerage Company, as well as apply sanctions (disconnection of water service) for non-payment of bills.
- Operation and maintenance of the sewer system may be delegated to a private contractor, either as a service contract (paid through the sewerage tariff collected by GWSC) or as a franchise (where the contractor is also responsible for collecting water and sanitation bills).

It is noteworthy that in Kumasi, solid waste is deposited in communal skips, even though these are not always regularly collected. This feature results in relatively litter-free streets and drains, and is possibly a key factor in the infrequent blocking of the shallow sewer system.

Now that 50% connection has been achieved in the Asafo pilot project area, consideration is being given to extending the coverage to the remainder of Asafo, as well as the other tenement areas in Kumasi. A major project is also underway to provide infrastructure to the large open-air market in Kumasi. Shallow sewerage has also been adopted for this project, which will service small informal traders.

2.4.6 Kanana, Vereeniging (South Africa)

The only attempt at implementing a shallow sewer system in South Africa that the study identified was in a peri-urban settlement outside of Vereeniging in Gauteng. This was an entirely community driven process, with some financial and technical assistance from a South African NGO (Homeless People's Federation, 1997; *Mail and Guardian*, Oct 24-30 1997, p 32). Unfortunately, this initiative has floundered, it seems largely due to political conflicts between the community representatives and the local authority.

The construction of shallow sewers in Kanana was part of a larger "self-help" initiative by the community to build houses and infrastructure without government subsidies. The community has developed a number of saving schemes to which members contribute on a weekly basis, and then can take loans for housing development. However, this has led to conflicts with the local authority and developers, related to private sector involvement in infrastructure development. This conflict is believed to have led to the assassination of the community leader who was driving the "self-help" process.

About 38 houses belonging to a saving scheme were designated by the community as the area that would pilot the shallow sewer system in Kanana. They took a loan, bought the materials and constructed the house connections and block feeder sewers, connecting into a nearby manhole of a large collector sewer. The capital cost for materials was estimated at about R500 per dwelling, including a toilet, with all design and labour being provided by the NGO and local residents. There was some technology transfer and exchange visits with the Orangi Pilot Project in Karachi, through the Homeless People's Federation. The intention was for the residents to maintain the block sewer.

The local authority did not accept the standard of the construction and the unauthorised connection to the connector sewer. The town engineer indicated that the community had used low grade pipes that would deform and block under soil loads. The system was thus disconnected, while the local authority has begun the implementation of a full waterborne sewerage system as part of an infrastructure upgrading project throughout the area, using housing subsidies. However, it is unclear how the operating costs of this new system will be financed, noting that the community may not take responsibility for maintaining a sewerage system that the council has implemented.

Unfortunately, the shallow sewer system has never operated and the effectiveness of its technical functioning and proposed management arrangements is tested. The community is now waiting for the full sewerage project and no further work is being done on the shallow sewerage.

However, two key lessons can be learned from this experience. Firstly, there is a desire by some South African communities to construct and maintain their own sewerage systems, in the absence of government programmes. This provides the basis for implementation of shallow sewerage systems in South Africa.

Secondly, it is imperative that the local authority and community engage in a dialogue and understand the opportunities and constraints within which each group is operating. This is even more important for a community driven process, such as Kanana, where the local authority can prevent the process from moving forward. This requires widespread dissemination of information about intermediate sanitation technologies, particularly aimed at technocrats and councillors in local authorities. On the other hand, communities that are attempting these types of initiatives need the specification of appropriate standards that they may use, in terms of materials, construction and design.

2.4.7 Important Lessons from the International Experience

Shallow sewers have been successfully applied in a number of developing countries under different conditions, as illustrated by the above case studies. Although shallow sewers are widely applicable, the international experience has indicated that the following elements are more likely to result in successful implementation:

- Create a dedicated multi-disciplinary shallow sewer development team in the water services provider, with social, construction and operations skills.

- Focus on formal or informal settlements with higher densities (greater than 30 dwellings per hectare), that represent a threat to environmental health, in order to reduce the cost per household.

- Perform social marketing of the shallow sewer system before project initiation, in order to create the demand required for high connection rates, involving the presentation of the advantages and disadvantages of different sanitation system alternatives and targeted health and hygiene education.

- Conduct intensive customer consultation during planning and implementation, based on a survey of the physical, social and economic settlement characteristics, in order to develop acceptable sanitation alternatives, system configurations, financing options and maintenance arrangements.

- Implement pilot demonstration projects in each new settlement during the planning phase, in order to provide community experience with the system and increase demand.

- Allow gradual customer driven expansion of the system, coordinating trunk and block sewer development with household connections on a block scale.

- Give preference to socially stable communities with legal land tenure, because residents are generally required to make investments in the area and resident turnover reduces the effectiveness of education programmes.

- Emphasize areas with historically proven records of cost recovery for water or other services.

- Use local contractors and labour, particularly on block feeder sewers and household connections, thereby transferring skills into the community for later operation and maintenance.

- Provide appropriate training and close supervision of local contractors to ensure quality control of the system construction, particularly for flat sewer gradients, thereby avoiding later operation and maintenance problems.

- Perform education programmes on system use and health and hygiene, as well as capacity building for local maintenance, during and after project implementation.

- Devolve responsibility for maintenance of house connections and block sewers to residents (or a third party), and ensure the commitment and capacity for maintenance of the trunk sewers is present in the water services providers.

- Develop maintenance management arrangements that are sustainable and flexible, during the planning and implementation phases, clearly defining the responsibilities of the water services providers, residents and any third parties.

- Agree the tariffs and mechanisms for collecting service fees during the consultation and planning process, and combine this with water supply billing where possible.

- Adopt appropriate design specifications for shallow sewers (as outlined in section 2.2.3; Mara 1996a&b; UNCHS-HABITAT, 1986), and use PVC pipes to overcome the problems of sulphide corrosion associated with longer residence times of sewage in the sewers.

- Attempt to link in with the provision of water supply, solid waste management and storm water drainage, because the lack of these services may cause failure of the shallow sewer system. For example, inadequate water use reduces flushing, refuse can lead to blockages and storm water intrusion can result in surcharge of the feeder or trunk sewers.

This chapter has provided a technical and institutional overview of shallow sewer systems, with reference to the international experience. The next chapter provides an estimation of the probable financial costs of shallow sewer systems in South Africa and compares these with the costs of other sanitation alternatives.

3 APPRAISAL OF SHALLOW SEWERS FOR SOUTH AFRICA

3.1 Introduction

The preceding chapter has reviewed the experience and applicability of shallow sewers internationally, as well as the management arrangements required for their effective and sustainable implementation. The key lessons learned from this experience are that shallow sewers are suited to settlements with:

- higher population densities - greater than 160 people per hectare (i.e. 30 dwellings per hectare);
- adverse geo-technical conditions, including steep, waterlogged or rocky areas;
- irregular layout and informal dwellings;
- low to medium water usage, using cistern or pour flush toilets - 30 to 150 ℓ/capita.d;
- social cohesion and a sense of permanence/tenure; and
- reasonable cost recovery for services, particularly water supplies.

This chapter presents an appraisal of shallow sewer systems applicability under the particular conditions currently found in South Africa. It also identifies possible constraints created by the existing technical, institutional and financial arrangements in the South African sanitation sector.

3.2 Applicability for Different South African Settlements

As indicated in the previous chapter, the use of shallow sewers is associated with specific technical, social and management requirements. These requirements are met to varying degrees in different types of settlements found in South Africa, depending upon the existing physical-infrastructural, social and institutional-financial character of the settlement.

The following discussion provides an overview of different settlement types in which shallow sewers may be applicable, and evaluates the key issues that may determine their successful implementation. Higher-income residential areas (i.e. monthly income higher than R5 000/household) will generally adopt and pay for conventional sewerage systems and shallow sewers are not technically viable at lower densities (i.e. gross densities of less than 15 du/ha), and thus these types of settlement are not addressed.

3.2.1 Greenfield Developments

Development of a new settlement provides significant latitude in terms of the planning and layout of a shallow sewer system. However, prospective residents are less likely to be actively involved in the planning and construction of shallow sewers, which may have an impact on the sustainability of their financing and maintenance. The international experience has indicated that implementing shallow sewer systems in greenfield developments can lead to problems, unless there is an identifiable target community or the service provider takes responsibility for maintaining the system (including the block feeder sewers). Three distinct types of greenfield development may be identified for the purposes of shallow sewer implementation.

a. Medium income developments

Shallow sewers may be implemented in new developments for medium-income households (greater than R3 500/household), where off-site sanitation is required, but the costs of conventional sewerage are too high. These are generally planned settlements with erf sizes between 200m^2 and 400m^2 (i.e. 15 to 40 du/ha). These households do not qualify for government subsidies and thus the developer must raise the capital and recover all costs from the future residents. Furthermore, these residents are unlikely to take part in construction or maintenance of the system. Under these conditions, the implementation of shallow sewerage is a technical solution, without the delegated management arrangements.

b. Low income developments, with an identifiable target community

High density (i.e. 30 to 60 du/ha) resettlement schemes may be developed for an identified lower-income community who quality for infrastructure subsidies, generally back-yard or informal shack dwellers. Shallow sewers may be appropriate for the more dense settlements, or those with adverse geo-technical conditions. The existence of an identifiable group of target residents enables some degree of consultation and participation in the planning and construction of the settlement, particularly if there is a financial advantage to them. This allows the community to negotiate and agree any financial and management arrangements required for implementing a shallow sewer system. Shallow sewers provide a potential solution in these areas, but extensive consultation and community involvement is required for sustainable operation.

c. Low income developments, without an identifiable community

Although new low-income housing developments (i.e. 30 to 60 du/ha) may be technically appropriate for shallow sewers, and may qualify for infrastructure subsidies, the lack of community involvement during planning and construction both increases the capital costs and reduces the "ownership" of the system by the future residents. These factors are likely to negatively affect the scope for delegated management of the system, as well as the possibilities for cost recovery, which are required for the sustainability of the system in these communities. People in these settlements tend to have low levels of income, which restricts the implementation of shallow sewers without delegated management. Furthermore, they should only be used in those settlements that have intermediate water supply levels (i.e. at least yard taps or tanks), because the user awareness that is required for low water usage is less likely to have occurred.

3.2.2 Upgrading Formally Planned and Serviced Urban Areas

The main characteristics of these settlements, which are usually in the urban core, are that they were formally laid out and provided with services at some time in the past, even though the superstructure is not necessarily a formal house. This historical service provision tends to exclude them from current infrastructure subsidy arrangements, even if household incomes are less than the R3 500 per month cut-off. The residents generally have *de facto* recognition of tenure, even where this has not yet been legally defined.

Internationally, shallow sewer systems have been successfully implemented in low- to medium-income planned settlements. The presence of an identifiable community improves the potential success of the system, but the key problems revolve around financing. Thus, the importance of community acceptance of responsibility for construction and management is increased, particularly in lower income settlements. Formally planned settlements may also be separated into three groups, for the purposes of shallow sewer implementation.

d. Medium income formal areas

Shallow sewer systems are usually only applicable for upgrading these existing formal settlements, if they currently have inadequately functioning on-plot sanitation (usually septic tanks or LOFLOS). These areas have densities of about 15 to 40 du/ha, with yard or household water supply, and are generally located in peripheral urban areas and small towns. If the area was previously provided with a reticulated sanitation system that has failed, this failure usually requires rehabilitation, maintenance and/or user education for the existing system, rather than the development of an entirely new shallow sewer system. The income of the residents in these areas generally disqualifies them from access to national infrastructure subsidies, even where the area did not previously benefit from infrastructure development. Therefore, the full costs of the system would have to be borne by the residents or the local authority. Furthermore, these residents are more likely to require maintenance to be performed by the service provider or a third party, for which they would have to pay. The application of shallow sewers in this situation is again likely to be a technical solution, without the delegated management arrangements of shallow sewer systems, but with cost recovery from residents.

e. Lower income planned areas

This category includes both formal township developments and site-and-service schemes, and thus the dwelling superstructure may be a formal house, an informal shack or even a traditional structure. Densities are generally medium to high (i.e. 30 to 60 du/ha) with water supply through communal standpipes or yard connections. Implementation of shallow sewers systems is only appropriate in these settlements when an existing on-plot sanitation system is inadequate; if there was previously a sewerage system which has failed, this system should rather be rehabilitated and properly managed. The residents have generally benefited from grant financing during the initial area development and thus do not qualify for additional national infrastructure subsidies. The community or local authority would therefore have to finance the capital costs. The regular planned layout of these settlements simplifies the construction of shallow sewers, while the potential cost savings associated with in-kind contributions of labour from the community should improve the likelihood of delegated management arrangements for construction and maintenance. These factors indicate that shallow sewers with community construction and management are likely to be an attractive option in these settlements.

f. Over-densified previously planned areas

Some previously planned and serviced settlements in the urban core areas of South Africa have become increasingly dense (i.e. 40 to 100 du/ha) through the development of "back-yard shacks". They generally have a mixed formal-informal nature, in terms of dwellings and services. Income distribution is highly skewed, while water supplies to an area may include the entire range from communal standpipes to household connections. The densification has generally led to the failure of the existing sanitation systems, whether these are on-plot or sewered, because the loads have exceeded the original design capacities. The back-yard shacks are usually permanent, even though the residents may be temporary. Most back-yard residents are poor and would require financial assistance for the capital costs of shallow sewer systems. However, the lack of "ownership" by back-yard residents may restrict the potential support and "investment" in the project by the community, as well as disqualify these residents from access to national capital subsidies within the existing area. This is further complicated by the previous development of these areas, which potentially disqualifies the area from access to these subsidies. A more viable alternative is the development of a new greenfields site with shallow sewers for these back-yard residents (see settlement type *b*). Although these settlements would benefit from shallow sewers with delegated management, these systems may not be appropriate unless the residents and/or landowners are willing to invest both finances and labour in the area. A possible alternative approach may be to connect shallow block feeder sewers into the existing trunk sewers in an area that has already been sewered.

3.2.3 Upgrading Informal Unserviced Settlements

An increasingly large number of South Africans live in unserviced informal settlements in the urban core, on the urban fringe or in rural areas. The residents are usually poor and therefore normally qualify for national infrastructure subsidies. However, access to these subsidies has largely depended upon the type of local authority under which the area falls, particularly whether it is urban or rural. The issue of land tenure also has important consequences for access to subsidies. The potential transience of the community may have a negative impact on the likely extent of commitment to a shallow sewer system. Shallow sewer systems may provide a technically appropriate solution in the denser informal settlements, while the low household incomes increase the likelihood of these residents being willing to accept responsibility for construction and maintenance of parts of the system. Furthermore, the presence of an identifiable community enables the required consultation and participation during all phases of the project cycle. Internationally, shallow sewer systems have been proven to provide a viable sanitation solution in dense informal settlements, once community support and financing have been arranged. The implementation of shallow sewers in unserviced informal settlements may be addressed under three categories.

g. Informal urban settlements, with access to subsidies

Implementation of a shallow sewer system may be considered in dense informal urban settlements (i.e. up to 100 du/ha) that have access to capital subsidies. The possibilities for success are improved, both because the capital financing is potentially available and there is generally an existing upgrading process with community commitment. Shallow sewers are particularly suited to areas that are being provided with yard connections. Other key issues, such as tenure and the relationship with the local authority, are also likely to have been addressed during the planning process. However, delegation of responsibility for management and operating costs is likely to be critical to the sustainability of the system, because of the lower income levels and high unemployment rates common in these areas. The denser settlements in this group represent an excellent opportunity for shallow sewer implementation, with delegated responsibility for management.

h. *Informal urban settlements, without subsidies*

Shallow sewer systems may also be considered for informal urban settlements without capital subsidies. These settlements also have densities up to 100 du/ha and are generally located on marginal land, with steep slopes, rocky conditions or in flood plains, and usually have limited services, with communal standpipes at best. Shallow sewers are appropriate for these areas, but only once reliable water supply has been provided (at least communal standpipes, but preferably yard connections). The lack of capital would require that the community and/or local authority raise financing for materials in advance, while the community provides labour for construction and operation. This implies a resident association or local government driven process of consultation throughout the project cycle, as well as social stability and some degree of "ownership" of the area. Therefore, settlements without permanence in terms of tenure and resident turnover are not appropriate for shallow sewer systems. These problems are compounded in settlements in the urban periphery, which fall outside the urban local authority boundaries (see dense rural settlements below), because there is seldom a viable local authority to drive the process. Nevertheless, implementation of shallow sewer systems with delegated management in these settlements is possible, particularly if a sense of community-local authority partnership can be developed.

i. *Dense rural settlements*

Shallow sewer systems may be considered in the dense rural settlements (with densities up to 40 du/ha), but the limited existing services and marginal land may complicate the implementation. These areas are usually located in the former homelands and are generally managed by District, Regional or Representative Councils. These settlements typically have access only to sectoral infrastructure subsidies, with limited local authority capacity for financing and managing municipal services. The land is often communally owned, which makes the traditional leaders powerful stakeholders. There is generally a degree of stability and permanence both in the settlement and residents, despite the migrancy usually associated with rural areas. Where there is a viable local authority and community support, shallow sewers may be appropriate for the most dense rural settlements, particularly if responsibility is delegated and the system is linked to a limited maintenance treatment system, such as waste stabilisation ponds.

3.3 Possible Management Arrangements for South Africa

3.3.1 The Distinction between Internal, Connector and Bulk Infrastructure

It is necessary to distinguish between the various elements of the sanitation system, for institutional and financial purposes in South Africa. In terms of shallow sewer systems, these are (Figure 3.1):

- *Internal*, representing the sewerage reticulation, including the block feeder and trunk sewers linking the plots to the connector infrastructure for an entire settlement area, but excluding the house connections.
- *Connector*, which links the sewerage reticulation from the whole settlement to the bulk services, and includes the pumping and rising mains to the sewer outfall (if these are required).
- *Bulk*, which includes the outfall sewers, treatment facilities and effluent outfall.

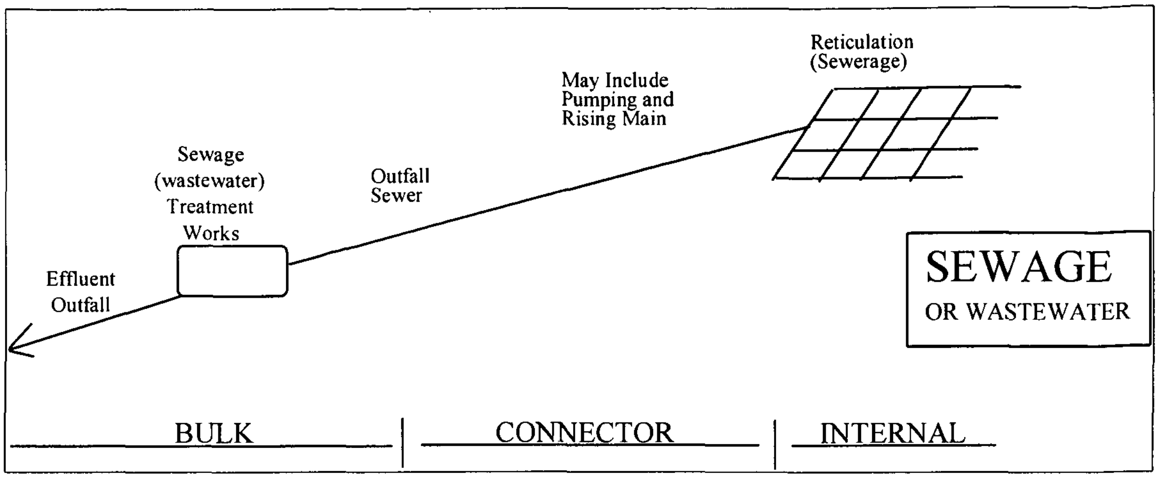


Figure 3.1 Internal, connector and bulk sewerage services.

3.3.2 Institutional Arrangements

The Water Services Act (Act No 108 of 1997) differentiates between water service authorities and water service providers. The former is the sphere of local government that has been given executive responsibility for providing services. The service provider may be the service authority itself or a contracted water board, water committee or private company. Between them, these two institutions have the responsibility for planning, developing and managing sanitation services within their area of jurisdiction.

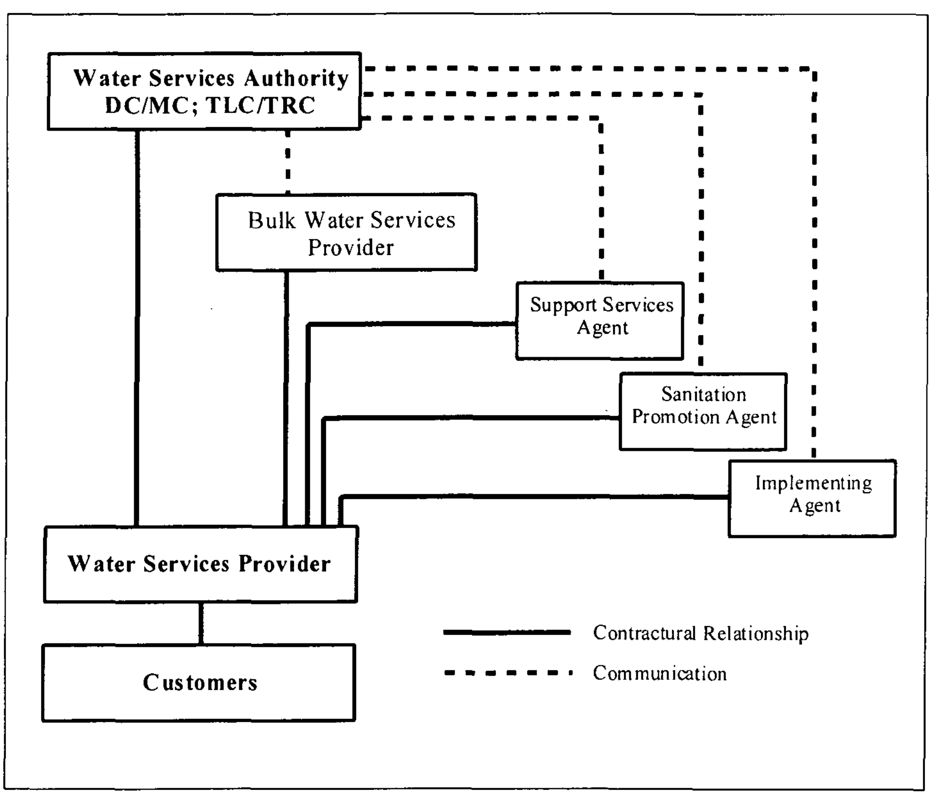


Figure 3.2. Possible institutional relationships for shallow sewerage systems.

Although many service authorities would be responsible for managing an entire internal, connector and bulk sewerage system, a regional bulk water services provider may be responsible for the external connector and bulk sewers and treatment facilities. An implementing agent may be contracted to plan, design and construct the shallow sewer system, but would leave the area after implementation of the project. In situations where the water service provider lacks capacity, certain functions may be contracted out to other organisations. For example the responsibility for operating and maintaining the internal sewer system may be contracted to a support services agent, while the social marketing, user awareness and health and hygiene education may be contracted to a sanitation promotion agent. Figure 3.2 outlines the possible institutional relationships between the different role players.

One of the main advantages of shallow sewer systems is the delegation of responsibility for construction and operation of the household connections and block feeder sewers to the residents. To be successful, this requires greater interaction between the service provider and the community in terms of capacity building and technical support, before and after construction. Although community interaction is often delegated to the implementing agent in South Africa, this is not appropriate for shallow sewer systems, because the service provider personnel need to build a relationship of trust with the community during the project planning and construction. This ensures that the required channels of communication and interaction are established before the system is installed. This relationship is indicated in Figure 3.2, where the service provider (or the designated support services and sanitation promotion agent) is responsible for community liaison and education, rather than the implementing agent.

Chapter 2 outlined the importance of the institutional arrangements for implementing shallow sewer systems. The key management issues that need to be resolved are:

- financing of the capital and operating costs, through subsidies, loans and household contributions;
- responsibilities for construction, including community labour contributions; and
- responsibility for operation and maintenance of the different parts of the system.

There are three possible scenarios for the implementation of shallow sewer systems. In each case the process is primarily driven by a different group, has different financial, construction and management arrangements, and has relevance to only some of the settlement types described in Section 3.2.

Local authority driven

Internationally, most successful shallow sewer initiatives are driven by a progressive local authority. The process requires intensive interaction between the service provider and customers (i.e. the community) during all phases of the project. To be effective, the local authority should have a dedicated team for shallow sewer systems, possibly as part of the sanitation, waste management or water services function. This team should have access to technical and social expertise, but consist largely of a community liaison officers and technicians. A distinction must be made between local authorities operating at:

- Micro and small scale (typically less than 50 000 people served): This would include small towns (with Local Councils) and dense rural settlements (supported by District Councils). These usually have limited personnel, are not structured into functional units, and thus are unlikely to be able to set up a dedicated shallow sewer team, particularly since less than 5 000 people would generally be served by shallow sewers.

- Medium to large scale (typically greater than 50 000 people served): This includes the larger towns and metropolitan areas, which would generally have professionally managed water service units, with the possibility of establishing a dedicated shallow sewer (or at least a sanitation) team.

Initially local authority driven implementation of shallow sewer systems, together with delegation of management arrangements, is likely to be most viable in the larger local authorities, because they generally have the required human resources. This is most appropriate where the residents have access to infrastructure subsidies (i.e. settlement types *b* and *g*), although it may also be feasible for low-income settlements without grant finance (i.e. settlement types *e*, *f* and *h*). Alternatively, shallow sewers may be implemented as a technical solution for middle income areas (i.e. settlement types *a* and *d*), without the delegated responsibilities for system construction and operation.

It is likely that in the short-term, local authority driven implementation of shallow sewers in smaller local authorities will only occur where the service provider takes full responsibility for construction and operation of the system. This implies implementation as a technical solution for middle income areas (i.e. settlement types *a* and *d*). Alternative management arrangements are only likely to be attempted once experience is gained and success is shown in the larger local authorities

Community driven

Shallow sewer systems may also be appropriate for local community based initiatives, particularly where there is a strong residents association that has access to technical support. These types of initiatives will only evolve in organised settlements in which there is *de facto* tenure or a sense of permanence. The community itself would contribute labour and finance, possibly with some external funding. Obviously a good working relationship with the local authority is an advantage, but is not necessary except where access to external subsidies is required or there is a need to link into nearby connector sewers.

Community driven initiatives are more likely to be sustainable, because the community has "ownership" of the project and is therefore likely to continue providing labour and/or finance for system operation. A desirable outcome would be one where these initiatives evolve into a mixed community-local authority initiative, with the two groups taking responsibility for those parts of the system for which they are most suited.

The Orangi Pilot Project and Kanana (section 2.4) are clear examples of this type of initiative. These initiatives are most likely to evolve in lower income informal settlements with an identifiable and cohesive community (i.e. settlement types *g*, *h* and *i*), as well as poorer formal areas (i.e. settlement types *b*, *e* and *f*).

Developer driven

To a limited extent, shallow sewers in greenfield developments may be developer driven, but this would only be during the planning and construction phase. Thereafter, either the local authority or community would have to take responsibility for operation. The limited consultation opportunities in new settlements implies that the local authority will have to manage the system, and therefore this scenario may be viewed as a technical shallow sewer initiative, with the developer acting as implementing agent for the service authority. The service provider would have to agree to the approach, which implies some form of local authority involvement, particularly where the system requires linkage to bulk and connector sewerage infrastructure. This approach is therefore only appropriate for middle income greenfield developments (settlement type *a*).

3.4 Financing of Shallow Sewers in South Africa

3.4.1 Introduction

As indicated in the preceding discussions, shallow sewers are likely to be most applicable for lower income communities with limited financial resources. Careful financing arrangements are therefore critical to both the implementation and sustainable operation of these systems.

Approaches to funding capital costs are dealt with separately to the financing of operational costs, in the following discussion. A distinction is also made between the financing of household connections, internal, bulk and connector infrastructure. The financial evaluation of the applicability of shallow sewer systems in a settlement must consider the affordability of both the capital and operating costs together, if they are to be sustainable. This needs to take the particular management arrangements required for shallow sewers into consideration.

3.4.2 Typical Capital Funding Approaches

The capital cost of a shallow sewer system may include (see Section 4.2.2):

- project implementation ("soft") costs, such as consultation, design, training and social marketing;
- construction ("hard") costs of the internal infrastructure, such as site preparation, materials and labour;
- construction costs of bulk and connector infrastructure; and
- general shallow sewer programme administration costs of the service provider, although this is closely linked to the "soft" project implementation costs and operational costs.

There are three basic sources of capital funds, namely grant funding, local authority funds and household contributions. Using these sources, capital costs may be funded in the following three general ways.

Fully grant funded

In some cases, capital grants (or subsidies) from national programmes or donor funding agents may cover the entire capital costs of implementing a shallow sewer system (see Chapter 4 for capital costs estimates of shallow sewer systems). However, national grant programmes have strict requirements about the recipient household income levels and the use of the allocation, while donor funding is quite limited and is usually allocated to pilot projects. The following national grant programmes may be used for shallow sewer systems:

- *Housing subsidy* provides R16 000 for households with total monthly income less than R3500, who have not previously benefited from infrastructure provision. The subsidy may be used for internal infrastructure and/or the top structure, and should be adequate to fund shallow sewer systems as part of a service package to greenfield developments (i.e. settlement types *b* or *c*) or in-situ upgrading (i.e. settlement types *g* or *i*). Housing subsidies have not been widely available to rural communities.

- *Sanitation subsidy* provides up to R600 for programme implementation and R600 for construction, with the same constraints as the housing subsidy, except that the focus has been on rural communities (i.e. settlement type *i*). Budget cuts have severely curtailed the availability of the sanitation subsidy, but innovative alternative approaches are currently being explored (NaSCO, 1998a). Under certain conditions, the sanitation subsidy may be adequate to fund the internal infrastructure capital costs of a shallow sewer system.

- *Consolidated Municipal Infrastructure Programme (CMIP)* provides R3 000 per household with a monthly income under R3 500 per month. Currently, it may only be used for the rehabilitation of bulk, connector or internal sewerage infrastructure, not for development of new infrastructure. Therefore, it cannot be used for any component of a new shallow sewer system. The only possible exception is the rehabilitation of existing connector or bulk sewerage infrastructure into which a shallow sewer system may connect[1].

Currently, grant funding is channelled through local authorities, which implies that a local authority (or developer) driven process is most likely to be associated with this full grant funding approach. However, these grant programmes may not necessarily cover the general shallow sewer programme administration costs of a service provider, which implies that these may have to be financed through other revenue. Furthermore, there is little opportunity for capital grant funding of bulk and connector wastewater systems, which implies that full grant funding is limited to those areas with excess capacity in the bulk and connector systems.

When full grant funding is available, there is the possibility to provide intermediate to high levels of service, which includes shallow sewers. However, these service levels can have relatively high operational costs, which may be unaffordable for the local authority and community. This may lead to local authority

[1] If shallow sewers are to be widely implemented in South Africa, it may be necessary to extend the use of CMIP to new bulk and connector infrastructure associated with intermediate sewer systems, such as shallow sewerage.

bankruptcy and system failure. Thus, evaluation of the affordability of both capital and operational costs is imperative.

Mixed funding

The capital costs of shallow sewer implementation are most likely to be funded from multiple sources, including national capital grants (subsidies), local authority funds and community contributions. The mixed funding approach is most likely to be local authority driven, because it requires coordination and management of a number of stakeholders. Grant funding from national programmes is most likely to be used for financing the capital costs of internal infrastructure, as indicated above.

Local authority funds will most often be used to fund the capital costs of bulk and connector infrastructure, as well as part of the internal infrastructure where national grants are not available and household contributions are not adequate. Local authorities have a range of funding options for capital projects:

- *District Council levies* are generally raised from commerce and industry, and may used for capital works in any local authority or settlement in the DC area of jurisdiction.
- *Local Council capital accounts* present the opportunity for cross-subsidisation of capital contributions to shallow sewer systems from other sectors (e.g. industry), other services (e.g. water or electricity) and other residential areas (e.g. high income or fully reticulated areas).
- *Local Authority borrowing* defers the recovery of capital costs, which must be paid over time with interest from the operating account.

Finally, household contributions may be required to cover the capital costs of household connections and part of the internal infrastructure. This may be in the form of a monetary connection fee and/or through the provision of labour during construction. Shallow sewers are particularly suited to the use of unskilled labour from recipient households. This is most appropriate in low-income areas, where affordability is low. It also represents a precursor to delegated management arrangements, because the inhabitants learn about the system and a degree of "ownership" is engendered. A household connection fee covering a significant portion of the capital costs is appropriate in middle income areas, where shallow sewers are implemented as a technical solution. A small connection fee should be charged, even in low income areas, because this provides an indication of affordability for the operating costs, which is critical for sustainability.

The appropriate division between the three general funding sources will largely depend upon the type of settlement:

- Capital costs of house connections and internal infrastructure for low income greenfield and informal settlements (types *b*, *c*, *g* and *i*) are likely to be financed through capital grants supported by household contributions, while local authority funds will be used to finance bulk and connector infrastructure.
- Household contributions and local authority funds will be used to finance capital costs for middle income, previously serviced low income settlements and informal settlements without access to capital grants (types *a*, *d*, *e*, *f* and *h*). The household contributions should cover the costs of house connections and some internal infrastructure, while the local authority funds may cover internal, connector and bulk infrastructure costs – the relative split should be based on community affordability.

Community financed

Community driven processes are likely to require community financing, possibly with some technical and financial assistance from external non-governmental organisations. There are a number of ways that communities can finance the capital costs shallow sewers, a combination of which is most likely:

- *Up-front connection fees* from savings or personal loans.
- *Labour contributions* to construction, particularly excavation and laying pipes for house connections and feeder sewers.
- *Community savings* where each household contributes a small amount of money each week, which is then used as seed money for the project.
- *Community loans* that are usually raised from government, commercial lenders or NGOs, once the

community has shown the capacity to save (this approach is being explored by NaSCO as an alternative to the sanitation subsidy).

Community contributions must cover the cost of internal infrastructure, but the contributions to bulk and connector infrastructure are less clear. In cases where the shallow sewer system can link into an existing bulk system, the bulk and connector costs are implicitly financed by the local authority. This approach should be supported by local authorities, because the community will by necessity take responsibility for operation and management of the internal infrastructure.

Alternatively the community must also finance the development of localised treatment facilities, such as communal septic tanks or waste stabilisation ponds. This may substantially increase the capital costs of the system, although local labour may also be used to construct these systems and thereby keep the costs down.

3.4.3 Typical Financing Approaches for Operating Expenditure

Sustainable operation of shallow sewer systems requires financing of the operational costs of the shallow sewer service provision, including the costs of (see Section 4.2.3):

- *Customer relations* from the service provider, such as ongoing education, awareness and training programmes.
- *Loan repayments* for funds borrowed for the capital costs, which includes interest.
- *Bulk and connector* infrastructure operation and maintenance, including pumping and wastewater treatment.
- *Internal* infrastructure operation and maintenance, possibly differentiating between trunk sewers and block feeder sewers.
- *Administration* of the system, including a portion of the service provider's overhead, financial (billing) and technical management costs.

As with capital funding, there are three sources of financing for operational costs, namely operational grant subsidies (for low-income households), local authority funds (implying cross-subsidisation) and household contributions. There are also three general ways in which the operational costs of shallow sewer systems may be financed. These reflect alternative management arrangements for different household income groups, as outlined below. In all cases, households are responsible for the maintenance of house connections.

Full service provision

This alternative represents the purely technical solution for shallow sewer implementation, whereby the service provider takes responsibility for operating the internal, as well as the bulk and connector infrastructure. National policy requires communities to pay the full costs of operation and maintenance, so these costs should be recovered. Limited affordability in lower income areas implies that full service provision should only be considered for middle income settlements (types *a* and *d*). These areas should pay the full operational costs of the shallow sewer system, similarly to residents with full waterborne sewerage. However, cross-subsidisation between industrial and residential services is common within an urban area.

Cost recovery for sanitation services is typically even worse than other services, which implies that these costs should be collected through other mechanisms. The most common mechanisms are to include sanitation service costs as a:

- percentage (typically between 30% and 50%) of the water bill, which reflects the expected waste water;
- flat rate per household for sanitation services, billed with the household rates or municipal rent; or
- percentage of the property valuation, billed as part of the household rates or municipal rent.

Shared local authority-community responsibility

The most common management arrangement for shallow sewer systems in lower income settlements (types *b*, *e*, *f*, *g*, *h* and *i*), is likely to involve shared responsibility for operation. Communities would be responsible for the block feeder sewers and the local authority would operate the trunk (street), connector and bulk sewer systems. This may be associated with higher customer service costs, because delegation generally requires greater (not less) interaction between the service provider and the community, while the operational costs for internal infrastructure may be significantly reduced.

The local authority would incur operational costs, some of which should be recovered from the community or through operational grants from national government. The current Inter-Governmental Grants (IGG) will be completely replaced by the Equitable Share Programme, by the year 2002 and 2005 in urban and rural areas, respectively. The equitable share is not an additional source of funding, and in many urban local authorities, it will result in a reduction of grant financing compared with the IGG. The Equitable Share allocates R80/month to a local authority, for every household earning less than R800/month, and thus may be used to partly subsidise the operational costs of shallow sewer systems, particularly where delegated management has been adopted.

However, this is unlikely to be adequate to fund the full operational costs. Some level of household contribution is likely to be necessary, and may be raised through the water bill, rates or rent (as outlined above). This should include at least the operational costs of the internal infrastructure and loan repayments, but part of the administration, customer service and bulk-connector operational costs may be waived in the interests of equity. These may largely be viewed as fixed costs and may be recovered from sectors or areas with full sewage reticulation.

Community administered

Community driven implementation of shallow sewer systems occurs largely without local government involvement. Therefore, the community itself has responsibility for operation and maintenance of the internal infrastructure, at a minimum. This responsibility may include localised treatment facilities, where these were necessary. These costs must be covered by financial and labour contributions from each beneficiary household. Usually the required system ownership and community-based organisations would be in place for a community driven process to succeed, so the likelihood is that these responsibilities would be honoured.

The relatively limited operational costs of the bulk and connector infrastructure should be waived by the local authority under these circumstances, in the interests of cooperation, because of the significant savings associated with delegated responsibility for internal infrastructure operation.

4 THE COST OF SHALLOW SEWERS IN SOUTH AFRICA

4.1 Introduction

This Chapter presents a breakdown of the likely costs of shallow sewer systems in South Africa, based on typical unit costs of the different components. The estimation has been separated into capital and operating costs. These cost estimates are compared with typical costs of other sanitation alternatives in South Africa, taking account of various settlement density and layout characteristics, as well as the applicability of the various systems under different conditions.

4.2 The Costs of Shallow Sewer Systems

4.2.1 The Costing Approach

Notwithstanding the Kanana experience, no operational shallow sewer system has been developed in South Africa. Therefore, the cost estimates derived for this report were based on the hypothetical design and costing of the internal infrastructure for shallow sewer systems in two settlements for which layouts were available. One was a formally planned township development of 650 sites in Harrismith (Figure 4.1), while the other was an existing unplanned informal settlement of 535 dwellings on three neighbouring plots in the Winterveldt (Figure 4.2).

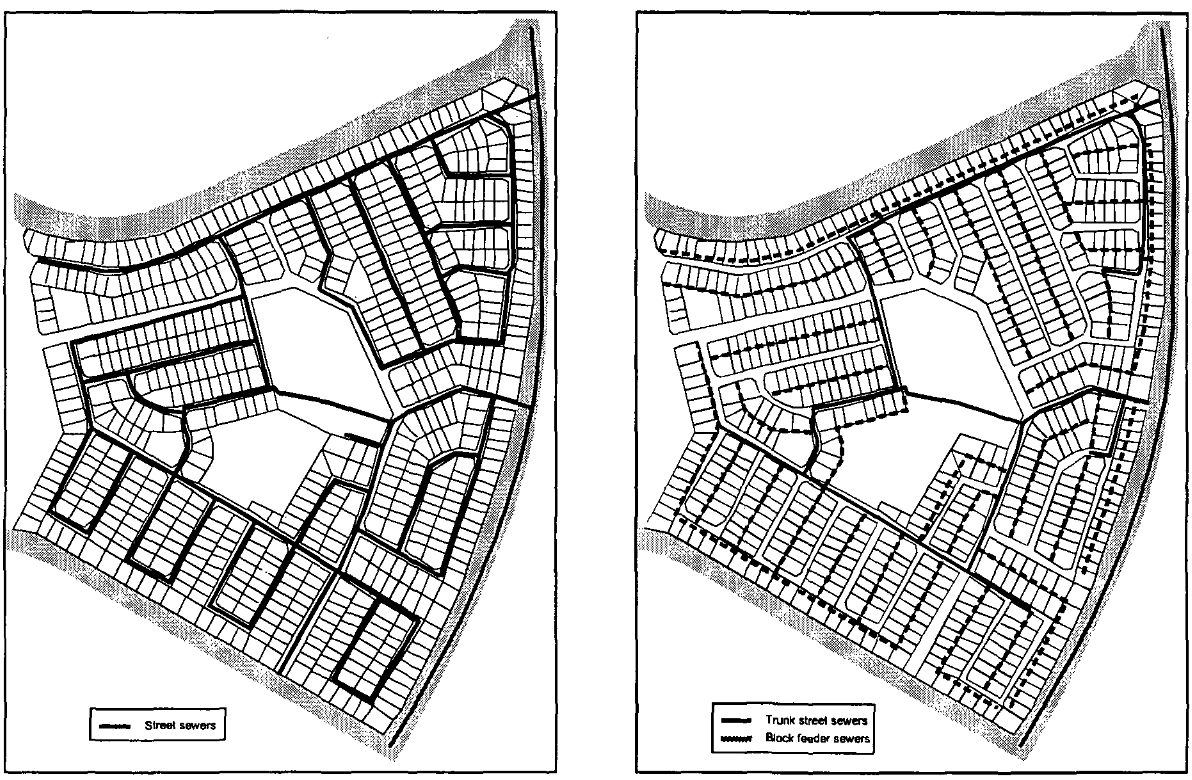


Figure 4.1. Conventional and shallow sewerage layout in the formal township development.

The base situation was designed for a gross density of 30 du/ha, on a flat gradient (0.1% slope) without the need to excavate rock. The costs for settlements with densities of 15 du/ha and 60 du/ha, gradients of 1% and 3%, and rock at 1 m depth (representing adverse geo-technical conditions) were evaluated for comparison.

Both back-yard and front-yard shallow sewer systems were designed for the formal area, and the costs were compared to the costs of a conventional sewerage system designed for that area. Only a shallow sewer system was designed for the informal settlement, because the irregular layout, unstable shack dwellings and low water consumption (standpipes and yard connections) would not allow the development of conventional sewerage. Here it is more relevant for shallow sewers to be compared to Ventilated Improved Pit-latrines (VIPs).

The conventional sewerage system was designed in accordance with SABS 1200 (1982), the "Red Book" (Dept. of Housing, 1994) and common engineering practice. On the other hand, the shallow sewer system was designed in accordance with the criteria outlined in UNCHS-HABITAT (1986).

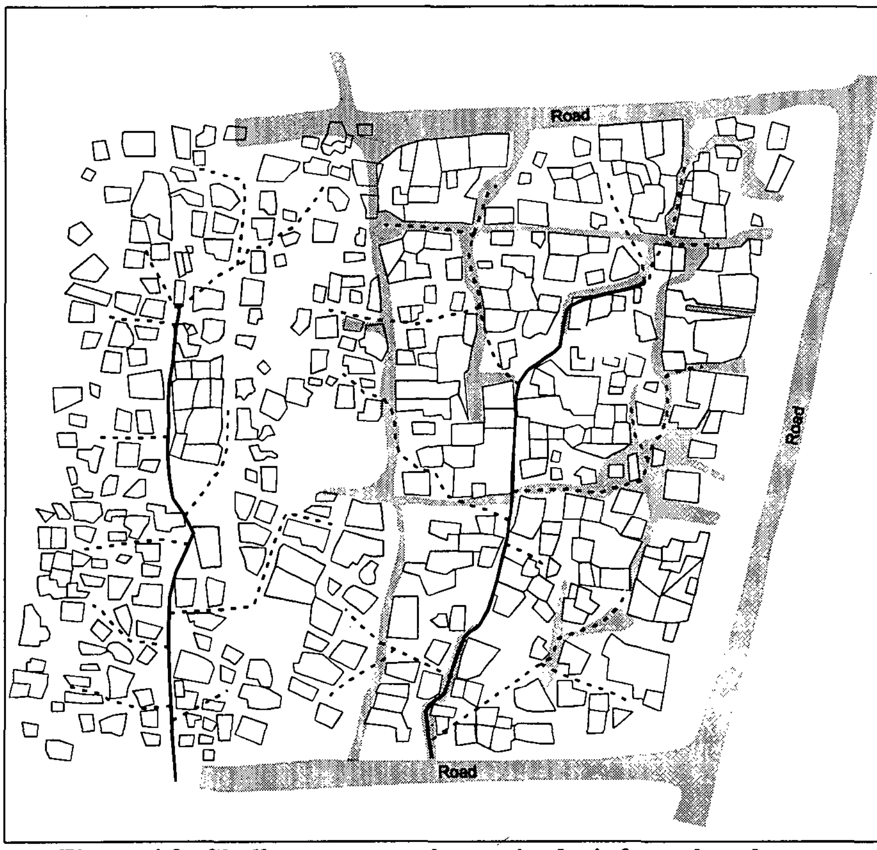


Figure 4.2. Shallow sewerage layout in the informal settlement.

4.2.2 Capital Costs

The estimation of the capital costs was based on a design schedule, with associated unit costs (rates) obtained from recent tenders for similar sized conventional sewerage projects. The summarised design schedules for the base situation associated with the formal township and informal settlement are presented in Appendix A. These schedules include project initiation costs and total construction costs (at contractor's rates) for the internal sewerage infrastructure and house connections (excluding VAT).

Project Initiation Costs

The implementation of shallow sewer systems generally requires extensive consultation and training of the local community, particularly where they are to assist in the planning and construction of the system. An average of 5% of the total construction cost was assumed for consultation and 10% for training and capacity building. These costs may be incurred by the local authority and/or developer, and are assumed to include general overheads associated with a shallow sewer programme. However, they are not incurred in conventional sewerage construction. An 8% planning and design fee was assumed for both shallow and conventional sewer systems.

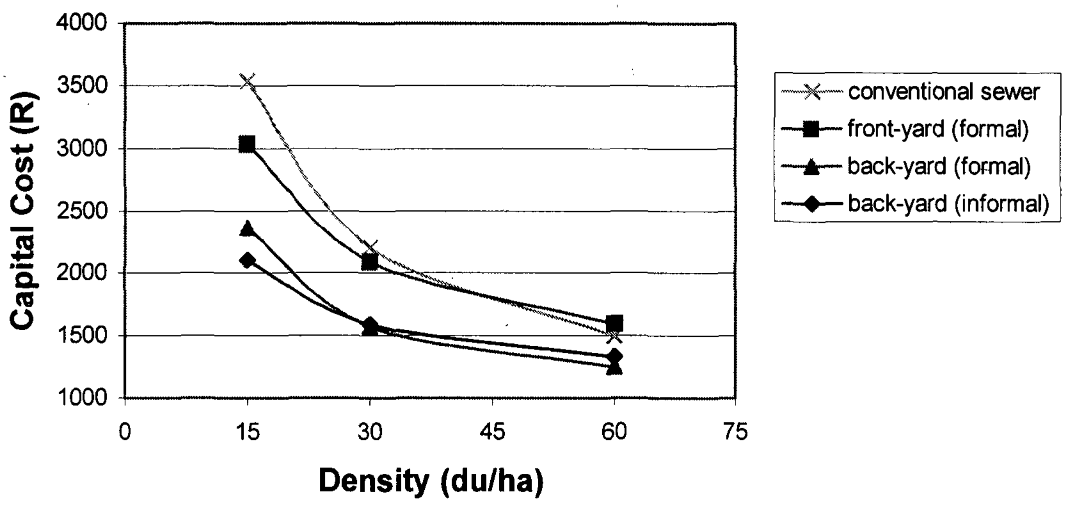
Capital construction costs of internal infrastructure

Construction costs were separated into the following, based on typical design schedules:

- Preliminary and general, which represents site establishment costs assumed to be 20% of the total construction cost for a project of this size.
- Excavation, which includes trenching, backfill and compaction at different pipe depths, as well as additional costs for excavation of rock.
- Pipework, at varying diameter for trunk and feeder sewers, as well as erf connections.
- Manholes and inspection chambers, at various depths.
- House connections, including on-site excavation and plumbing for pipework, grease traps and household fixtures (i.e. R250 for a toilet and plumbing), but not the top-structure (about R800/site).

The total capital costs per household for internal infrastructure and house connections associated with the three sewer systems are presented in Table 4.1, for different density, slope and geo-technical conditions. The capital costs are presented graphically for different densities in Figure 4.3, assuming the flat gradient and 'no rock' alternative.

Figure 4.3. Capital cost per household
for different sanitation alternatives and densities



From this analysis, the capital costs of a contractor constructed back-yard system ranges from 65% to 85% of a conventional sewerage system, whereas the front-yard shallow sewer system does not result in significant savings of capital costs.

Table 4.1. Capital costs for internal sewerage infrastructure under different conditions.

Settlement type	Formal Township						Informal	
Sewerage system	*Back-yard*		*Front-yard*		*Conventional*		*Back-yard*	
Geo-technical	no rock	1 m rock	no rock	1m rock	no rock	1 m rock	no rock	1 m rock
30 du/ha @ 0%	1570	2180	2100	2770	2210	4020	1590	1910
30 du/ha @ 1%	1510	1900	2030	2420	2100	3900	1560	1740
30 du/ha @ 3%	1510	1900	2030	2420	1850	3510	1560	1740
15 du/ha @ 0%	2370	3580	3040	4384	3540	6380	2110	2760
60 du/ha @ 0%	1250	1550	1600	1940	1500	2780	1330	1500

As would be expected, the situation with rock at 1 m depth throughout the settlement increases the cost of conventional sewerage (80% to 90% increase) far more than shallow sewerage (20% to 50%) increase.

This is largely due to the need for street sewers to be laid at a depth greater than 1 m, which represents most of the conventional system, whereas about 60% of the shallow sewers are on plots and thus can be laid at shallower depths. Therefore, shallow sewers are particularly appropriate for areas with geo-technical problems. A similar conclusion may be made for areas with a high water table.

These costs assume that a contractor constructed the entire system. However, an advantage of shallow sewer systems is their suitability for using local residents' labour, particularly in excavation and laying of sewers within the blocks (i.e. feeder sewers, inspection chambers and household connections). Table 4.2 provides a breakdown of the capital costs between the different items on the costing schedules (in Appendix A), for the base case of 30 du/ha on flat terrain and no rock. The estimated percentages for conventional sewerage are consistent with those reported by Palmer Development Group (1994a).

Table 4.2. Total capital item costs for internal sewerage infrastructure.

Settlement type	**Formal Township[1]**						**Informal[1]**	
Sewerage system	*Back-yard*		*Front-yard*		*Conventional*		*Back-yard*	
	R 000	*%*	*R 000*	*%*	*R 000*	*%*	*R 000*	*%*
Project initiation	164	16	219	16	90	6	167	16
Site establishment	143	14	191	14	224	16	119	14
Excavation trunk sewers feeder and erf	121	12 (5) (7)	158	12 (4) (8)	329	23 (23)	52	6 (2) (4)
Pipework trunk sewers feeder and erf	100	10 (4) (6)	137	10 (3) (7)	189	13 (13)	46	5 (2) (4)
Manholes precast manhole inspection	212	21 (2) (19)	322	24 (2) (22)	268	19 (19)	255	30 (2) (28)
House connection	283	28	335	25	335	23	241	28
Total cost	***1023***	***100***	***1362***	***100***	***1435***	***100***	***850***	***100***
Cost per house	*1570*		*2100*		*2210*		*1590*	

1 Note: the formal township has 650 plots, while the informal settlement has 535 dwellings.

The feeder sewers and house connections represent about 60% of the total capital costs of the shallow sewer system. Of this, 25% may be assumed to be labour and 75% materials costs (Palmer Development Group, 1993a). If the labour is provided by the community, this represents a 15% reduction to the total capital costs of the system. Therefore, back-yard shallow sewers may be developed at 50% to 70% of the capital cost of conventional sewerage.

Capital costs of bulk and connector infrastructure

The capital costs of the bulk and connector infrastructure required for shallow or conventional sewerage systems were not dealt with in the costing analysis. They are likely to be similar for shallow and conventional sewerage, although the lower water requirement of shallow sewers may be associated with lower capacity (and cost) pipelines and treatment facilities.

Localised treatment facilities, such as waste stabilisation ponds, may cost from R800 to R4 000 per household to construct, depending upon the site conditions and effluent standards. Construction costs for conventional bulk and connector sewer systems, with treatment, are typically about R1 500 per household, but this may range between R600 and R8 000. However, shallow sewer systems would typically require only 60% of the water required by conventional sewerage (see below), and thus the average capital cost of bulk and connector infrastructure for shallow sewerage may be assumed to be R1 000 per household (60% of R1 500). This cost must be added to the capital costs of the internal infrastructure for both shallow and conventional systems, particularly when they are being compared to on-plot sanitation alternatives.

General administration costs

As outlined in section 3.4.2, there are a number of general administration costs to the water services authority and water services provider associated with a capital development programme for shallow sewer systems. These have not been incorporated in the analysis, because estimation of the capital oriented portion of the total administrative costs, which should be allocated to shallow sewer development, is difficult and these are likely to be similar for all sanitation alternatives (i.e. VIPs to conventional sewerage).

4.2.3 Operational Costs

There is very little international information about the actual operational costs of shallow sewer systems. Therefore, the individual components of the operating cost had to be estimated for the delegated management alternative. The technical solution would have similar operating costs to a conventional system (Table 4.3).

Customer relations costs

The effective functioning of a shallow sewer system requires ongoing social marketing and capacity-building of the local community by the sanitation service provider. This is particularly important where management of the block feeder sewers has been delegated to the community. This would involve a community liaison officer (CLO), possibly with the support of a technician.

Once the system is implemented and is functioning, a settlement of about 650 households may require 3 half-day visits from a CLO and technician per month. A CLO-technician salary would be about R3 000/month, implying a total monthly cost of about R6 000 for 20 working days, or R300/day. Additional costs would be for travel and professional support (of about half an hour per month) to the CLO and technician.

Time:	3 half-days	@	R 300/day	=	R 450
Travel:	2 trips of 50 km	@	R 1.00/km	=	R 100
Professional:	half hour	@	R 200/hour	=	R 100
Total:					R 650

This is equivalent to about R1.00 per household per month, but would result in a reduced administration cost compared to the monitoring requirement for a conventional sewerage system.

Internal infrastructure operation and maintenance

The operation and maintenance of internal reticulation for conventional sewerage is typically estimated as 0.5% of the capital cost per month, which is on average about R8.00 per household per month. Although shallow sewer systems may have slightly higher maintenance requirements for internal infrastructure, the operating costs will generally be lower. Thus an operating cost of 0.5% of capital is also applicable to shallow sewers.

Assuming a technical solution, with the service provider maintaining all feeder and trunk sewers, the household operating cost for the front-yard system would be about R7.50/month and the back-yard system would be about R6/month.

However, with delegated management of the feeder sewers, which account for about 70% of the total sewer length and about 60% of the sewer construction cost, the internal infrastructure operating cost to the service provider of a back-yard shallow sewer system, may be reduced to about R3.00/month per household. An additional R0.50/month may be considered for occasional major maintenance of the block feeder sewers, which is beyond the capacity of the community.

If depreciation of 2% per year is considered, this is equivalent to about R3/month per household for conventional sewerage. In the delegated management responsibility situation, this would be equivalent to about R1.5/month per household for a back-yard shallow sewer system.

Bulk and connector operation and maintenance

Average conventional sewerage operating costs of bulk and connector infrastructure are about R1.5/month per household for waste stabilisation ponds, and about R5/month per household for conventional treatment. However, the lower water consumption of shallow sewer systems (60% of conventional - see below) should be considered. This would imply that the applicable operational costs for shallow sewer systems with lower levels of water supply would be about R3/month per household. This would automatically be the case where sewerage charges were collected through water bills or sales.

Administration costs

The above costs do not include the service provider's administration, particularly financial billing and professional staff time. Depending upon the size and efficiency of the service provider, this may range from R4/month per household up to about R12/month per household (with an average of about R8/month). The portion of this that should be charged to shallow sewerage is unclear, particularly if the billing is already being performed for water or rates (see section 3.4.3). Furthermore, these costs should not be charged in the delegated management situation, otherwise the total operational costs of the shallow sewer system would increase significantly and the likely support from the community would be diminished. However, if the 60% ratio proposed for bulk operation costs is adopted, the equivalent shallow sewer cost would be R5/month. This would include the R1/month for customer relations, so the additional cost is only R4/month per household for administration.

Table 4.3. A breakdown of the total operating costs for different sewerage systems (Rand).

	Customer Relations	*Internal*		*Bulk and connect.*	*Admin.*	***Total cost***	*Water costs*
		feeder	*trunk*				
Back-yard shallow sewer	1.00	3.00	3.00	3.00	4.00	**14.00**	8.00
Front-yard shallow sewer	1.00	4.50	3.00	3.00	4.00	**15.50**	8.00
Conventional sewerage	-	-	8.00	5.00	8.00	**21.00**	15.00

Water costs

Although it is not a direct cost for the shallow sewer system, the smaller flushing volumes required for effective functioning of shallow sewer systems may lead to significant household savings. Shallow sewers can operate using a 1 *ℓ* pour flush cistern, whereas conventional sewerage requires about 3 *ℓ* per flush. This implies that shallow sewers can operate at household water use of about 30 *ℓ*/capita.d (200 *ℓ*/household), which can be met with a yard tank. Conventional sewerage systems are only appropriate with water use greater than about 50 *ℓ*/capita.d.

A typical water bill for a shallow sewer linked household using 50 litres per capita per day would be about R15/month (assuming R2/k*ℓ*). In general, it may be assumed that shallow sewers require about 60% of the water use of conventional sewerage, which is equivalent to a saving of about 4 k*ℓ*/month. This implies a R8/month reduction in the monthly water bill, which represents a large portion of the total operating cost of a shallow sewer system.

In Brazil, where operational costs for shallow sewers are collected through water sales, these are specified at between one and two thirds of the water bill. Taking the above R15/month water bill, this would be equivalent to R5 to R10 per month, which is the correct range for the operational cost to the service provider of a delegated management shallow sewer system; i.e. R7.00/month: R1 (customer service) + R3.00 (internal) + R3 (bulk).

4.3 Cost Comparisons

The above analysis has outlined the capital and operating cost estimates for shallow and conventional sewerage in both formal and informal settlements. This section compares these with the costs associated with Ventilated Improved Pit latrines (VIPs) in South Africa, and considers the international experience.

4.3.1 Cost Comparisons for South African Conditions

Table 4.4 presents average capital and operating costs for VIPs, back-yard and front-yard shallow sewers and conventional sewerage in South Africa, distinguishing between internal and bulk infrastructure. The capital costs assume construction by a contractor, whereas the operating costs represent the full operating costs of the system.

Table 4.4. Typical capital and operating costs for different sanitation alternatives (Rand).

	Capital[1] (R)		Operating (R/month)			Total Annualised (R/month)
	Internal	*B & C*	*Internal*	*B & C*	*Admin*	
VIP	1250	-	2.00	1.00	-	13
Shallow sewer systems						
- back-yard	1500	1000	7.00	3.00	4.00	31
- front-yard	2000	1000	8.50	3.00	4.00	36
Conventional sewerage	2100	1500	8.00	5.00	8.00	45

[1] Capital costs are for construction of the entire system by a contractor.

VIPs have lower operating costs than sewerage systems and thus the life cycle cost needs to be estimated to allow comparison. The total annualised cost per household per month (TACH) is also presented, based on a design period (N) of 20 years for the sewerage systems and 15 years for VIPs, assuming a discount rate (d) of 5%. The equation upon which this is based is:

$$\text{TACH (R/month)} = (O + M) + \frac{\text{Capital}}{12} \cdot \frac{d(1+d)^N}{(1+d)^N - 1}$$

Table 4.5. Capital and operating costs per household assuming community participation in construction and operation (Rand).

	Capital[1] (R)		Operating[2] (R/month)			Total Annualised (R/month)
	Internal	*B & C*	*Internal*	*B & C*	*Admin*	
VIP	950	-	1.00	1.00	-	10
Back-yard shallow sewers	1250	1000	4.00	3.00	4.00	26
Conventional sewerage	2100	1500	8.00	5.00	8.00	45

[1] Capital costs of VIPs and back-yard shallow sewer assume community labour contributions for block sewers.
[2] Operating costs of VIPs and back-yard shallow sewers assume delegation of management responsibility.

Table 4.5 presents the capital and operating costs assuming community participation in construction and delegated management of the block feeder sewers for the back-yard system and for VIPs, and their comparison to conventional sewerage. This illustrates the reduction in cost achievable through community participation and that back-yard shallow sewers provide a viable intermediate sanitation alternative. The total cost is approximately halfway between that of VIPs and conventional sewerage.

Ventilated Improved Pit-latrines (VIPs)

A VIP per household of 8 people is the RDP minimum sanitation in South Africa. It provides an on-site sanitation alternative, with relatively low capital cost (R1 000 to R2 000) and little operating requirements. However, provision needs to be made for the pit to be desludged every 5 to 15 years. The operational cost is equivalent to R2/month for ongoing maintenance and periodic desludging, and R1/month for treatment and disposal of the sludge, which includes the cost of health and hygiene awareness. Capital costs increase quite considerably under adverse geo-technical conditions (i.e. up to 50%).

VIPs are most appropriate in low to medium density settlements (< 40 du/ha), because with higher densities, space becomes a limiting factor and the possibility of groundwater contamination is increased.

4.3.2 Comparison with the International Experience

Table 4.6 provides an indication of international costs of shallow sewer systems compared with conventional sewerage (Reed, 1995; Netto, 1992; UNCHS-HABITAT, 1986). These are largely based on the Brazilian experience, and include situations where communities were involved in construction and operations of the shallow sewer systems. At the current exchange rate of R5.75 per US$, these estimates are similar to those calculated for South Africa (Tables 4.3 and 4.5).

Table 4.6. Typical international capital and operating costs of sewerage systems (US$).

	Capital cost ($/household)		**Operating cost ($/month)**
	Internal	*Bulk & Con.*	
Shallow sewer systems	220 - 450	300 - 700	1.5 - 2.5
Conventional sewerage	400 - 1000	300 - 850	5

4.4 Shallow Sewer Tariffs and Payment Options

The above costs were input to the Sanitation Services Model (Bee Thompson, *pers comm*, 1998), which analyses capital and operating costs and compares them to proposed revenues within a local authority area. The modelling was done for an upgrade of sanitation services to informal areas in a large metropolitan substructure with about 1.5 million people. The results of this analysis are quite instructive, in terms of the cost of providing sanitation.

The current situation in this metro sub-structure is that there are a total of about 280 000 households, of which about 77 500 are informal and 16 500 are back-yard shacks. About 14% of these households have income below R800 per month (i.e. Equitable Share threshold), while about 73% are below R3 500 per month (i.e. Housing Subsidy). Of the informal households, about 80% have inadequate water supply and sanitation (i.e. simple pits), with the remainder having LOFLOS and communal standpipes.

For the purposes of this analysis, it was assumed that the sanitation backlog would be redressed by providing about 5 000 shallow sewer connections per year in areas with densities above 30 du/ha and 5 000 household VIPs per year for the less dense areas. The capital cost of shallow sewers at this density is about R2 150 per household (with a toilet top-structure), which is assumed to be covered by the housing subsidy. The equivalent capital cost for a VIP is R1 900 per household. The capital cost of the bulk and connector sewerage infrastructure is incurred by the metro and is recovered through the bulk sewerage operating charge of R1.20/k*l* levied on the sub-structure.

Yard taps (or tanks) are provided with the shallow sewer system, which equates to a wastewater return of about 7.5 k*l*/month per household (i.e about 80% of the average 60 *l*/capita.d water use). This is about 60% of the water use for a full house connection. The operating cost per customer to the service provider for shallow sewerage with delegated management of the block feeder sewers was estimated at R4/month for administration and R5/month for internal reticulation and customer support (based on the actual current operating expenditure). The bulk charge of R9/month (7.5 kℓ at R1.20/kℓ) is also applicable, which implies a total operating cost to the service provider of R18/month for shallow sewerage with delegated management. This estimate is equivalent to the total annualised cost of R26/month presented in Table 4.5, once the annualised capital cost of the internal infrastructure (R8/month) is deducted. The cost would increase to about R21/month where the service provider is responsible for maintenance of the block feeder sewers.

The equivalent operating cost of providing full waterborne sewerage to low income households (using about 25% more water) was estimated to be R27/month, while middle and high income households had full waterborne sewerage costs of R36 and R 46 per month, respectively. This does not include the additional cost of the higher water usage for waterborne systems, nor the additional capital costs for the internal infrastructure. The equivalent operating cost of VIPs is only about R2/month.

Following this scenario, sewerage tariffs of R17/month, R26/month and R54/month were proposed for shallow sewerage, full waterborne to low income and full waterborne to middle and high income areas, respectively. No tariff is charged for servicing the VIPs, as the administration required to collect this would be higher than the R2/month operating cost. The sanitation model application highlighted the importance of reducing the current 30% non-payment rate to below 10%, if these tariffs are to be financially viable.

The method of collection for these sanitation tariffs is critical to payment rates and cost recovery. Three approaches were outlined in section 3.4.3. Of these, incorporating the sanitation charge into the water tariff is the only realistic option in an informal settlement, because land rates and rents are seldom collected. This would imply that the R17/month must be collected through water sales of about 9.5 kℓ/month, which equals a sanitation tariff of R1.80/kℓ. This is equivalent to a 35% to 60% surcharge on the R3.00/kℓ to R5.00/kℓ water tariff that would be common for yard taps (or tanks) in an informal settlement. Interestingly this is the range of sanitation tariff that is commonly used in Brazil.

On the other hand, if the shallow sewer system was developed in a formal residential area, the possibilities for collecting revenue through rates or rental are greater. In this case, the shallow sewer tariff would be R17/month. Any of these tariffs may be decreased through greater cross-subsidisation or use of the Equitable Share grants. However, care should be taken to evaluate the income groups of the recipient households.

5 IMPLEMENTING SHALLOW SEWER SYSTEMS IN SOUTH AFRICA

5.1 Recommendations

5.1.1 Applicability of Shallow Sewers in South Africa

Shallow sewer systems provide a viable intermediate sanitation alternative, with a total cost between VIPs and conventional sewerage. They may be preferable to VIPs in denser (greater than 35 du/ha) formal and informal peri-urban settlements. They are unlikely to be a viable alternative to VIPs in rural settlements, because densities are generally too low. Shallow sewerage also provides a less expensive alternative to conventional sewerage in low to medium income formal urban residential areas. A significant advantage is that shallow sewer systems are appropriate where water use is between 30 and 60 ℓ/capita·d (i.e. pour flush toilets with yard tanks or yard taps), which may be too high for VIPs and too low for conventional sewerage.

The settlements for which shallow sewers are most appropriate, are:

- Upgrading of low-income informal settlements, where there is access to capital grant financing and community willingness to take responsibility for construction and operation of the block sewers.
- Upgrading of low to middle income formal or informal settlements with on-plot sanitation, where the community is committed to shallow sewers, has raised funds for materials and will take responsibility for construction and operation of shallow sewers.
- Upgrading of middle income settlements with on-plot sanitation, where cost recovery for services is high and the community is willing to pay the local authority for the full capital and operating cost of the sewerage system; this represents the technical approach.

Although shallow sewer systems seem to be more appropriate for settlement upgrading, they may be applied in the following greenfield situations:

- Greenfield developments for an identified low-income community, with access to capital grant financing and a willingness to take responsibility for construction and operation of the block sewers.
- Greenfield developments for a middle income community, where full cost recovery for all services is expected (i.e. the technical approach).

Back-yard shallow sewers are most appropriate in informal settlements and where the community takes responsibility for operation. Front-yard shallow sewers are generally preferred by local authorities that are responsible for maintenance, because access to the sewers is easier.

However, there are a number of issues that need to be considered before shallow sewers can be implemented in these types of settlements throughout South Africa. These are addressed separately in the following four sections, namely technical, institutional, financial and social issues.

5.1.2 Technical Standards

The technical characteristics of shallow sewer systems have been described in Chapter 2, and are not reiterated here. However, these systems require a relaxation of traditional design and construction standards, and an associated education of the technical personnel who are responsible for their implementation and management.

- Technical design standards for sewer systems, such as local authority bylaws, the "Red Book" (Dept. of Housing, 1994) and SABS 1200 (1982), need to be relaxed. In particular, the use of smaller diameter sewers (i.e. less than 150 mm), shallower block sewer depths (i.e. only 400 mm cover), flatter sewer gradients with small diameter pipes (i.e. 1:167 slope for 100 mm pipes) and less stringent access requirements (i.e. inspection chambers rather than manholes).
- Building codes for household fittings and house connections should be relaxed, allowing local construction of fittings and connections, with less stringent connection requirements, albeit with quality control on trunk sewer access.
- The relaxation of design standards for shallow sewer systems is based on the assumption of high

connection rates. Therefore, shallow sewers should not be implemented in blocks where less than 75% of the residents have agreed to connect under the proposed financing and management conditions.

- Site-specific design of block feeder and trunk sewer system layout should be encouraged to minimise the costs of the system and allow the use of shallow sewers in irregular informal settlements.
- However, the standards should require consultation and user education of residents in cases where traditional standards are relaxed, to increase "ownership" and ensure appropriate use of the system.
- Similarly, community or small contractor capacity building should be required where construction or management of the system is delegated, thereby transferring maintenance skills into the community.

The last two points highlight the inter-relationships between relaxing design standards, delegating management responsibility and increasing community awareness, all three of which are necessary for efficient and sustainable implementation of shallow sewer systems.

5.1.3 Institutional Arrangements

For a shallow sewer programme in a particular local authority to be effective, with dedicated personnel being appointed, a relatively large number of shallow sewer connections are required (i.e. at least 5 000 connections to allow economies of scale). This level of implementation may take time to develop, particularly during the initial implementation of these systems in South Africa.

It is likely that only the larger metropolitan local authorities will have the resources to conduct and evaluate shallow sewers within the first few years, under a test case situation (see section 5.2). However, smaller local authorities may adopt these systems once the expertise has been developed within South Africa; in Brazil, there are some small towns of 15 000 households that have adopted shallow sewerage as the standard for all households.

The provision of shallow sewerage to a community requires clarification of the management arrangements and responsibilities of all role players. Section 3.3.2 outlines various possibilities, including full service provision by the service provider, delegated management to the community, and finally full community responsibility for the system.

Shallow sewer systems lend themselves to delegation of responsibility for construction and operation of part of the system to the recipient community. However, there are situations where the service provider may take full responsibility for construction and operation or the system:

- In lower income areas (or middle income areas where there is support), provision of labour for construction and responsibility for operation of the block sewers (and house connections) should be delegated to the community. The local authority should take responsibility for construction and operation of the trunk street sewers, connector and bulk infrastructure.
- In middle income areas where cost recovery has been proven, shallow sewers may be implemented as a lower cost sewerage alternative, whereby the local authority constructs and operates the entire sewer system (except house connections).

5.1.4 Financing

The capital costs of back-yard shallow sewers are generally about 70% (i.e. R1 500 per household) of the cost of conventional sewerage, dropping to as much as 50% under adverse geo-technical conditions. Operating costs for back-yard shallow sewer systems with delegated management arrangements should be about 60% of those for conventional sewerage systems (i.e. R4 for internal and R3 for bulk infrastructure per household per month). Together this implies a total annualised cost for back-yard shallow sewers which is about two thirds of conventional sewerage. The capital and operating costs of front-yard shallow sewerage are higher that back-yard systems (i.e. 80% to 95% of conventional sewerage).

The capital costs of back-yard shallow sewer systems are only about 20% more than VIPs at medium densities (30 du/ha) and are about the same cost at high densities (greater than 50 du/ha). However, the operating costs (even with delegated management) are about 4 times higher, which equates to a 100%

increase in total annualised cost for shallow sewer systems over VIPs. If the operating costs for bulk and connector infrastructure are not included, this annualised cost is only 50% that of VIPs.

Therefore, shallow sewers provide a financially viable and efficient alternative to conventional sewerage and have the advantage than responsibility for construction and operation of part of the system (i.e. the block feeder sewers) can be delegated to the community. However, they require greater cost recovery than VIPs, even with delegated management. Thus financing is a critical consideration for implementing shallow sewer systems. The following recommendations are pertinent in this regard:

- The capital costs of internal infrastructure (trunk and block sewers) and household connections should be financed through national grants (such as the housing or sanitation subsidy), with the remainder being provided by the community as an up-front connection fee and/or in-kind labour contribution.
- Implementation of shallow sewer systems in lower income communities should be conditioned on the acceptance of delegated management responsibility for the block sewers.
- Financial incentives (such as cost reductions) should encourage residents to provide labour for the shallow sewer development, particularly where responsibility for operation is to be delegated to the community.
- Middle income households that do not qualify for grant financing should pay the full capital costs of the internal infrastructure, particularly if the local authority is to take responsibility for operating the system.
- Where possible, the development of bulk and connector infrastructure for shallow sewer systems should be financed (subsidised) by local authorities using grants, loans or own funds. Currently, CMIP grants may not be used for sewer development, but the possibility of relaxing this condition for intermediate sewer systems (such as shallow sewerage) should be investigated with DCD.
- The service provider's administration costs for shallow sewer capital development within a local authority area (such as consultation, social marketing and capacity building) should not be recovered from the community, but rather be subsidised by local authority funds, due to the social and health benefits associated with improved sanitation.

Cost recovery for operational expenditure is critical to the sustainability of shallow sewer systems (as is the case with conventional sewerage). The following operational recommendations may be derived from this study:

- The tariff for shallow sewerage should be collected as a percentage of the water tariff, in settlements where cost recovery is relatively high. Otherwise, an average flat rate should be added to the monthly rent or rates bill.
- Implementation of shallow sewers should be avoided in communities with a poor historical record of payment for services, until the community has shown willingness to pay for other services.
- The shallow sewer tariff should reflect the position of shallow sewerage as an intermediate cost sanitation alternative between on-site VIPs and conventional full waterborne sewerage.
- Tariffs should be set to cover the full operational costs of the shallow sewer system, but taking account of possible national operational grant funding (i.e. the equitable share) and cross subsidisation for lower income communities.
- Tariffs should be reduced in line with the cost savings associated with delegated management arrangements, particularly for the operation of internal infrastructure.
- Where possible, a further reduction in the tariffs below the actual operating cost should be considered where the community takes responsibility for operating the block feeder system, in order to create an incentive for these management arrangements.

5.1.5 Social Issues

The needs for social marketing, consultation and user education have been clearly spelt out throughout this document, particularly the experience from international application (see Chapter 2). The viability of delegated management of sewer systems has not been tested in South Africa, and there may be significant cultural and political resistance. Addressing these issues is beyond the scope of this appraisal study, but should be carefully considered for any pilot studies aimed at testing the technology and management arrangements in South Africa.

5.2 South African Pilot Studies

This study has shown that shallow sewers may provide a viable sanitation alternative for peri-urban settlements in South Africa. The next step is to test the technology, management and financing of shallow sewers in a few pilot studies. These settlements that are chosen for these pilot studies should have the following characteristics, which should increase their chances of success. The settlement should:

- be part of a large municipality (> 500 000 people) with an existing water and wastewater department, which has shown an interest in exploring alternative approaches to service provision;
- have a density of between 30 and 50 du/ha, either formal or informal;
- have on-site water supply, preferably a yard tap, yard tank or house connection;
- have an existing inadequate on-plot sanitation alternative, which the community has recognised as a health problem;
- be relatively stable, with recognised tenure; and
- have an existing legitimate community organisation representing water and sanitation interests.

Based on these criteria, the metropolitan councils provide the best chance of successful piloting of shallow sewers. Three possibilities have been identified at this stage:

- Discussions with Durban Water and Waste have indicated that a settlement in Durban may provide an appropriate pilot study, particularly if combined with the implementation of a yard tank or roof tank water supply.
- Cape Town metropolitan council is piloting a number of appropriate technologies in association with the University of Cape Town, which may provide a vehicle for shallow sewer implementation.
- The town engineers from Vereeniging have indicated an interest in supporting the community driven shallow sewer initiative in Kanana, particularly with a delegated management approach.

5.3 Way Forward

The way forward for implementation of shallow sewers in South Africa has two elements, namely pilot studies and advocacy. Further research needs may be identified out of the pilot study implementation.

Pilot studies

One or more of the pilot study initiatives, or alternatives that meet many of the specified criteria, should be initiated as soon as possible. NaSCO is the most appropriate organisation to take this process forward, possibly by channelling donor funding into the process.

The implementation and operation of these pilot studies should be systematically evaluated, in order to guide further implementation. Such an evaluation may be funded by the Water Research Commission.

Advocacy

Shallow sewers are a new and relatively unknown technological approach for South Africa, while delegated management arrangements are a relatively untested concept. There should be two main areas of focus for advocacy to support the extension and implementation of shallow sewers:

- Shallow sewers will primarily be selected and implemented by local authorities (possibly through their service providers). Thus the town engineers should be targeted in terms of the applicability of these systems, whereas the financial and management advantages of these systems over conventions sewerage should be explained to the local authority politicians (councillors).

- The second area of advocacy should be towards national policies that may be used to promote intermediate sanitation alternatives, particularly with delegated management arrangements.

6 BIBLIOGRAPHY

Behrens, Roger and Vanessa Watson (1996) *Making urban places: Principles and guidelines for layout planning*. Urban Problems Research Unit. University of Cape Town Press. Cape Town.

Cotton, Andrew, and Richard Franceys (1991) *Services for shelter: Infrastructure for low-income housing*. Liverpool Planning Manual 3. Prepared at WEDC. Liverpool University Press. UK.

Department of Housing (1994) *Guidelines for the provision of engineering services and amenities in residential township development ("The Red Book")*. CSIR. Pretoria.

Dreyer, Lynette (1998) *The dynamics of community non-compliance with basic water supply projects*. WRC Report # TT 93/98.

Du Pissani, Julia (1998) *The operation and maintenance of settled sewerage systems in South Africa*. WRC Report # 708/1/98. Pretoria.

Eales, Cathy (1995) *Selecting sanitation technology: A review of the literature*. Prepared for Umgeni Water as part of the Sanitation Decision Support System Project.

Fourie, AB and MB van Reyneveld (1994) *Environmental impact of on-site sanitation: A literature review with particular application to South Africa*. WRC Report No. KV57/94. Pretoria.

Ghanaian Ministry of Local Government and Rural Development (1998) *Environmental Sanitation Policy*. Govt. of Ghana.

GHK (1998) *Practical development of Strategic Sanitation Concepts: Conceptual Framework and Outline of Pilot Project Process*.

Hogrewe, William, Steven D Joyce and Eduardo A Perez (1993) *The unique challenges of improving peri-urban sanitation*. WASH Technical Report No 86. Washington DC.

Kalbermatten, John M, DeAnne S Julius and Charles G Gunnerson (1982) *Appropriate sanitation alternatives: A technical and economic appraisal*. World Bank. The Johns Hopkins University Press. Baltimore.

Kumasi Metropolitan Assembly (KMA) (1991) *Strategic Sanitation Plan for Kumasi*, Republic of Ghana.

Mara, Duncan (1996a) *Low-cost sewerage*. John Wiley and Sons. Chichester. England.

Mara, Duncan (1996b) *Low-cost urban sanitation*. John Wiley and Sons. Chichester. England.

NaSCO (1998a) *Support to peri-urban sanitation strategy in South Africa: Summary of findings and recommendations*. Prepared by Makhetha Development Consultants.

NaSCO (1998b) *Clarification on the national sanitation policy around higher levels of service*. DWAF. Pretoria.

National Sanitation Task Team (NSTT) (1996) *National sanitation policy: White Paper*. RSA.

Netto, Jose M Azevedo (1992) *Innovative and low cost technologies utilised in sewerage*. Technical series No 29. Environmental Health Programme. Pan American Health Organisation. WHO. Washington DC.

Ninham Shand (1995) *The economic, environmental, legislative and procedural implications of alternative water and sanitation systems*. Prepared for CUSSP.

Otis, Richard J and D Duncan Mara (1985) *The design of small bore sewer systems*. Technical Advisory Group Technical Note No 14, Interregional Project INT/81/047. UNDP and World Bank. Washington DC.

Palmer Development Group (1993a) *Cost comparison of sanitation systems*. Sanitation Working Papers, WRC project – Urban sanitation evaluation. Cape Town.

Palmer Development Group (1993b) *Urban sanitation evaluation*. WRC Report No 385/1/93. Pretoria.

Palmer Development Group (1994a) *Layout, design and service options research project – report on Sanitation*. Urban Problems Research Unit. UCT. Cape Town.

Palmer Development Group (1994b) *Water and sanitation in urban areas: Financial and institutional review*. WRC Report No 561/5/94. Pretoria.

Palmer Development Group (1994c) *Water and sanitation in urban areas: Survey of on-site conditions*. WRC Report No 561/1/94. Pretoria.

Palmer Development Group (1994d) *Costing of water supply systems*. Working Paper for WRC project – Evaluation of water supply to developing urban communities. Cape Town.

Pickford, John (ed) (1997) *Water and sanitation for all: Partnerships and innovations*. Proceedings of the 23rd WEDC Conference. Durban, South Africa.

Pybus, PJ (1996) *Preliminary guidelines for private sector participation in water supply and sanitation services*. WRC Report No KV 81/96.

Reed, RS (1995) *Sustainable sewerage: Guidelines for community schemes*. WEDC. Intermediate Technology Publications. London.

SABS (1982) *1200 - Standardised specifications for civil engineering construction. LD: sewers*. Pretoria.

Salifu, Lukman (1998) *An appraisal of sewerage maintenance in Ghana*. KMA. Ghana.

UNCHS-HABITAT (1986) *The design of shallow sewer systems*. Nairobi.

Watson, Gabrielle (1994) *Case study on low cost urban waste water collection in Latin America: Condominial sewerage in Petrolina, Brazil*. World Bank Latin America Technical Environmental Division. Washington DC.

Watson, Gabrielle (1995) *Good sewers cheap? Agency customer interactions in low-cost urban sanitation in Brazil*. Water & Sanitation Division. World Bank. Washington DC.

Wright, AM (1997) *Towards a Strategic Sanitation Approach: Improving the sustainability of urban sanitation in developing countries*. UNDP-World Bank Water and Sanitation Programme. Washington DC.

APPENDIX A: SCHEDULES USED FOR COSTING THE SEWER SYSTEMS

Table A.1. Cost schedule for shallow and conventional sewerage in the formal township.
(650 households; 30 du/ha; 0.1% slope; rock at 1 m)

			BACK-YARD SS			FRONT-YARD SS			CONVENTIONAL		
	Item	*Rate*	*Qty*	*Total*	%	*Qty*	*Total*	%	*Qty*	*Total*	%
PROJECT INITIATION											
Consultation (5% of construction)			5%	49569		5%	62943		-	0	
Planning and design (8% of construction)			8%	79311		8%	100709		8%	163111	
Training and capacity building			10%	99138		10%	125887		-	0	
PRELIMINARY AND GENERAL											
Site establishment (20% of construction)			20%	198277	14	20%	251773	14	20%	407778	16
EXCAVATION (trench, backfill, compact)											
Trunk street sewers (160 mm)											
1-2 m	m	25		0			0		1067	26667	
2-3 m	m	40	567	22667		567	22667		1300	52000	
3-4 m	m	60	183	11000		183	11000		1283	77000	
4-5 m	m	90							750	67500	
Trunk street sewers (110 mm)											
1-2 m	m	25	733	18333		733	18333			0	
2-3 m	m	40		0			0			0	
3-4 m	m	60		0			0			0	
Block feeder sewers (110 mm)											
0-1 m	m	15	3217	48250		5300	79500			0	
1-2 m	m	25	817	20417		1067	26667			0	
2-3 m	m	40		0			0			0	
Erf connection (110 mm)											
0-1 m	m	15		0			0		325	4875	
1-2 m	m	25		0			0		1950	48750	
2-3 m	m	40		0			0		1300	52000	
Hard rock excavation	m3	120	0	0		0	0		0	0	
Total				120667	12		158167	12		328792	23
PIPE WORK (lay, joint, bed and test)											
Trunk street sewers (160 mm)	m	30	750	22500		750	22500		4400	132000	
Trunk street sewers (110 mm)	m	18	733	13200		733	13200			0	
Block feeder sewers (110 mm)	m	16	4017	64267		6350	101600			0	
Erf connections (110 mm)	m	16		0			0		3575	57200	
Total				99967	10		137300	10		189200	13
MANHOLES AND INSPECTION											
Precast concrete manholes											
0.5 - 1.0 m	#	1800		0			0		7	12600	
1.0 - 1.5 m	#	2000		0			0		32	64000	
1.5 - 2.0 m	#	2300	3	6900		3	6900		26	59800	
2.0 - 2.5 m	#	2700	2	5400		2	5400		17	45900	
2.5 - 3.0 m	#	3100	2	6200		2	6200		12	37200	
3.0 - 3.5 m	#	3500	1	3500		1	3500		8	28000	
3.5 - 4.0 m	#	4000		0			0		5	20000	
Inspection chambers											
household (0.4 - 1.0 m)	#	400	400	160000		650	260000			0	
block (1.0 - 1.5 m)	#	1000	30	30000		40	40000			0	
Total				212000	21		322000	24		267500	19
HOUSE CONNECTION											
Excavation to house (0-1 m)	m	12	3250	39000		5200	62400		5200	62400	
Pipework to house (110 mm)	m	15	3250	48750		5200	78000		5200	78000	
Grease/gully trap	#	50	650	32500		650	32500		650	32500	
Household fixtures no superstructure)	total	250	650	162500		650	162500		650	162500	
Total				282750	28		335400	25		335400	23
Total construction				*715383*			*952867*			*1120892*	
TOTAL IMPLEMENTATION COST				**1022998**			**1362599**			**1434741**	
Cost per household				***1570***			***2100***			***2210***	

Table A.2. Cost schedule for shallow sewerage in the informal settlement.
(535 households; 30 du/ha; 0.1% slope; no rock)

				SHALLOW SEWER		
	Item	*Rate*		*Qty*	*Total*	
PROJECT INITIATION						
Consultation (5% of construction)				5%	29735	
Planning and design (8% of construction)				8%	47576	
Training and capacity building				10%	59470	
PRELIMINARY AND GENERAL						
Site establishment (20% construction)				20%	118940	14
EXCAVATION (trench, backfill, compact)						
Trunk street sewers (160 mm)						
1-2 m	m	25		125	3125	
2-3 m	m	40		338	13500	
3-4 m	m	60			0	
Trunk street sewers (110 mm)						
1-2 m	m	25			0	
2-3 m	m	40			0	
3-4 m	m	60			0	
Block feeder sewers (110 mm)						2
0-1 m	m	15		1450	21750	
1-2 m	m	25		550	13750	
2-3 m	m	40			0	
Erf connection (110 mm)						
0-1 m	m	15			0	
1-2 m	m	25			0	
2-3 m	m	40			0	4
Hard rock excavation	m3	120		0	0	
Total					52125	6
PIPE WORK (lay, joint, bed and test)						
Trunk street sewers (160 mm)	m	30		463	13875	2
Trunk street sewers (110 mm)	m	18			0	
Block feeder sewers (110 mm)	m	16		2000	32000	4
Erf connections (110 mm)	m	16			0	
Total					45875	5
MANHOLES AND INSPECTION						
Precast concrete manholes						
0.5 - 1.0 m	#	1800			0	
1.0 - 1.5 m	#	2000			0	
1.5 - 2.0 m	#	2300		2	4600	
2.0 - 2.5 m	#	2700		2	5400	
2.5 - 3.0 m	#	3100		2	6200	
3.0 - 3.5 m	#	3500			0	
Total					16200	2
Inspection chambers						
household (0.4 - 1.0 m)	#	400		535	214000	
block (1.0 - 1.5 m)	#	1000		25	25000	
Total					239000	28
					255200	30
HOUSE CONNECTION						
Excavation to house (0-1 m)	m	12		3000	36000	
Pipework to house (110 mm)	m	15		3000	45000	
Grease/gully trap	#	50		535	26750	
Household fixtures no superstructure)	total	250		535	133750	
Total					241500	28
Total Construction					594700	
TOTAL IMPLEMENTATION COST					**850421**	
Cost per household					***1590***	

APPENDIX B: SANITATION IN GHANA – SITE VISIT

B.1 Introduction

A site visit to Brazil was originally proposed as part of this project. This had the aim of:

- observing the operation of a functioning system,
- discussing the managerial and institutional arrangements with those involved, and
- developing a network of international contacts with people or groups involved in the field.

A significant amount of literature is available on the Brazilian experience and this was incorporated into the study. There are also some shallow sewer projects in Ghana, and it was felt that these may be more relevant to South Africa. These projects have not been widely published and thus warranted more investigation, particularly since they are in Sub-Saharan Africa. A site visit took place from 25th to 31st July 1998.

Contact was made with various groups in Ghana that are involved in simplified or non-conventional sewerage, which includes approaches to management systems and institutional arrangements:

- Lukman Salifu of the Kumasi Municipal Assembly indicated that the Asafo Simplified Sewerage System pilot project would be of particular relevance, while there were other areas also be worth visiting.
- Adu-Gyamfi Abunyewa of the Tema Municipal Assembly set up a visit to the conventional systems in which they have developed aerated lagoons and communal septic tanks.
- Kofi Frimpong of Carlbro International arranged meetings with people involved in sanitation in Accra.

These systems represent attempts to address the technical, social and institutional issues around providing sustainable sanitation to urban areas and thus have particular relevance to South Africa.

B.2 Water Supply and Sanitation in Ghana

Water supply and sanitation are institutionally separated in Ghana. The Ghana Water Supply Company is responsible for bulk and reticulated water supply throughout the country, including the metering and collection of tariffs. On the other hand the local authorities are responsible for sanitation provision, but no mechanism has yet been developed to collect sanitation charges through the water tariff. As a result, sanitation provision has lagged behind water supply in the major centres. At the time of the site visit there was an initiative by the Ghanaian Ministry of Local Government and Rural Development (1998) as the lead sector agency, to develop an Environmental Sanitation Policy, which outlines the objectives, roles and strategies for sanitation provision by the year 2020.

The following discussion provides an indication of the current status of sanitation in Tema and Kumasi. Although Accra is the capital of Ghana, there is only about 5% sewerage coverage, mainly for the industrial and high-income housing estates, with most households depending upon private septic tanks.

B.3 Tema

Tema is Ghana's main port with many heavy industries and a population of about 100 000 people. Tema is a planned town and has a comprehensive sewerage system, serving both the industrial and residential portions. Most of the system is linked to conventional chemical treatment works, although there is a small residential area treated by communal septic tanks.

Unfortunately inadequate maintenance has led to the deterioration of the system and significant sand deposition, with sewage discharge to stormwater drains and water courses (Salifu, 1998). The system is currently being rehabilitated, involving the replacement of corroded conventional sewers, refurbishment of the three failing pumping facilities and provision of aerated lagoons. Tema municipality has relatively low capacity for maintenance of the system and unless alternative management arrangements are developed, the sustainability of this refurbishment is questionable. At the time of the site visit, Tema was exploring the possibilities of public private partnerships for service provision, initially in terms of solid waste management, but potentially for operation and maintenance of the sanitation system at a later time.

B.4 Kumasi

Kumasi is a much older town than Tema, with a population of about 770 000 people. Sanitation coverage is very low, with most of those households that have access to sanitation facilities being served by public toilets or bucket latrines. It was in this context that the Strategic Sanitation Plan of Kumasi was developed (KMA, 1991), one outcome of which was the Asafo Simplified Sewerage Scheme. This initiative is described in section 2.4.5 and is not addressed in detail in this appendix.

The Strategic Sanitation Plan also proposed the replacement of a bucket system with WC and communal septic tank systems in the formal single dwelling middle-income residential areas. Between 6 and 12 houses at a gross density of about 10 du/ha to 20 du/ha are connected to a communal septic tanks and small drainage field. These systems were observed to function relatively well, with occasional failures. The residents are responsible for maintaining these systems and use private operators for this purpose. Discussions with residents of a system that had blocked and been repaired, as well as one that had recently blocked, indicated that there was a willingness for all residents to contribute to the repair, even though the cost to each household were in the order of a quarter of their average monthly income. This indicates the community perceptions of the health and convenience benefits of this type of system, as well as their willingness to pay for sanitation.

This willingness to pay is also reflected in the widespread use of public latrines, which are connected to large septic tanks. These are franchised by the Kumasi Metropolitan Assembly to a private operator. The charge per use ranges between 30 and 50 cedis (equivalent to about 20 South African cents), which represents about 1% of the minimum daily wage of 3 000 cedis.

APPENDIX C: PICTURES OF SHALOW SEWERS FROM THE ASAFO SCHEME.

Plate 1. Excavation for shallow sewers.

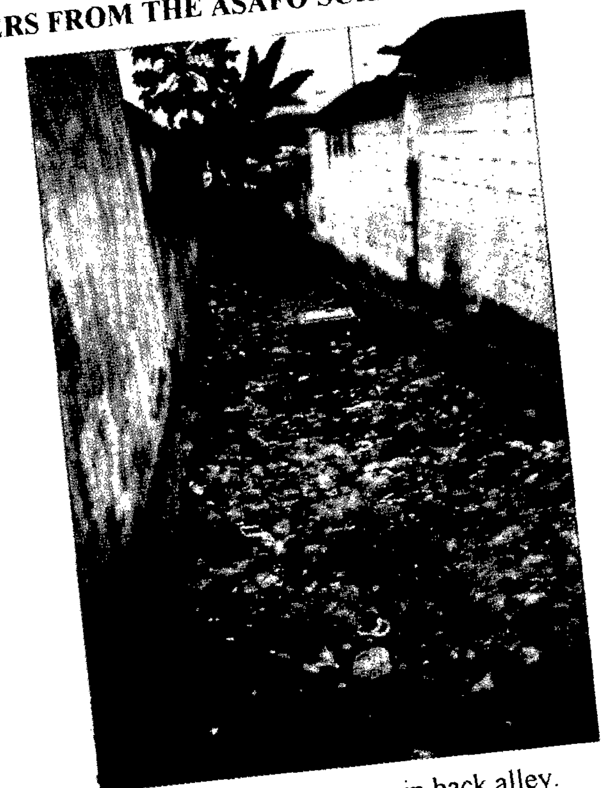


Plate 2. Shallow sewers in back alley.

Plate 3. Metal sleeve for sewer under road.

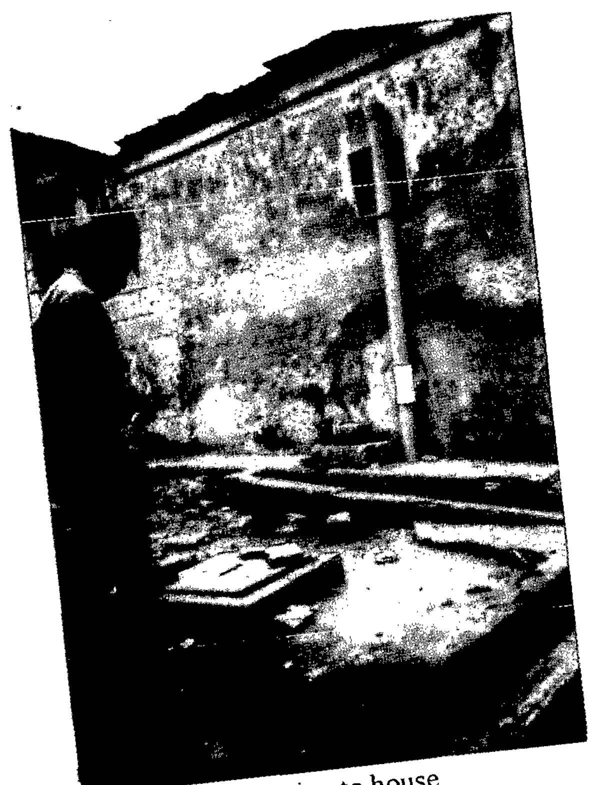


Plate 4. Connection to house.

Plate 5. Sidewalk inspection chamber.

Plate 6. Household inspection chamber.